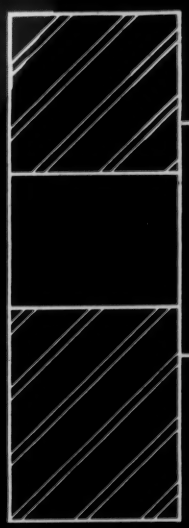
MACHINE DESIGN

July 1952



QUALITY CONTROL

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XUM

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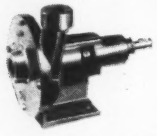

PEDESTAL MOUNTED PUMP—For use where flexible coupling or V-belt drive is desired. Essentially the same pump as package pump at left, except that bearing bracket is substituted for motor. A-C also furnishes motor, drive, control. See ratings at left.

VERTICAL MOUNTED PUMP — Open impeller unit with special cover plate and flange for vertical mounting. Used in air conditioning to save piping cost. Also used as coolant pump for machine tools. Capacities to 80 gpm; heads to 100 feet.

MACHINE DESIGN

JULY 1952, Vol. 24—No. 7

THE PROFESSIONAL JOURNAL FOR CHIEF ENGINEERS AND DESIGNERS

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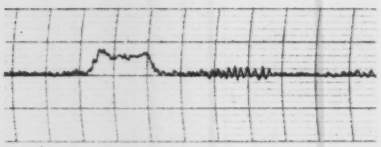
Over the Board

Jack Robinson

Charles E. Balleisen of Southwest Research Institute writes: "While reading the May issue of our favorite journal I was somewhat perturbed to find on Page 4 that the editorial staff didn't know how long it takes to say Jack Robinson. Feeling that this was a fundamental matter which should have been settled some time ago, I asked two of my assistants, Bob Doak and Luis Garza, to make a scientific investigation. They hooked up a microphone to a Brush recorder and produced a set of records similar to this one:



Reduced to plain English, their findings are that it requires 635 milliseconds, roughly $\frac{5}{8}$-second, to say Jack Robinson. As for three shakes of a lamb's tail, we have not seen a lamb within reach of our instrument, but we shall keep our eyes open."

While we're about it, how quick is a wink?

This Month's Cover

Contrary to first impression, those blue notes on the front cover are not the first measures of the National Anthem. Actually they represent a control chart, part of the overall design which Penton artist George Farnsworth has created to symbolize the subject of Dorian Shainin's article which begins on Page 102. Discerning readers will also recognize in the design a pair of probability curves, as well as a machine spindle transformed from a drawing into cold steel.

How About Round Trip?

Vast numbers such as the national debt fail to register on the mind of the average mortal until reduced to a per-person basis. An interesting figure of this kind was recently quoted by an English interplanetary scientist in discussing the establishment and maintenance of a "satellite vehicle" in an orbit around the earth. After telling about the fabulous cost of such a project, he pointed out that it would cost five thousand pounds or about $14,000 to transport one man from the earth to such a satellite. Add 15 per cent for Federal tax.

For Editorial Achievement

We take modest pride in announcing that MACHINE DESIGN has won two of a possible five "First Awards" in the latest annual editorial achievement competition sponsored by the publication *Industrial Marketing*. Entries which won first-place plaques were Randolph Chaffee's "Evaluating Engineers" (June 1951), judged the best single article among industrial publications, and the April 1951 issue, which was judged the best single issue. The bronze plaques were presented at a luncheon meeting during the National Industrial Advertisers Association convention in Chicago on July 2.

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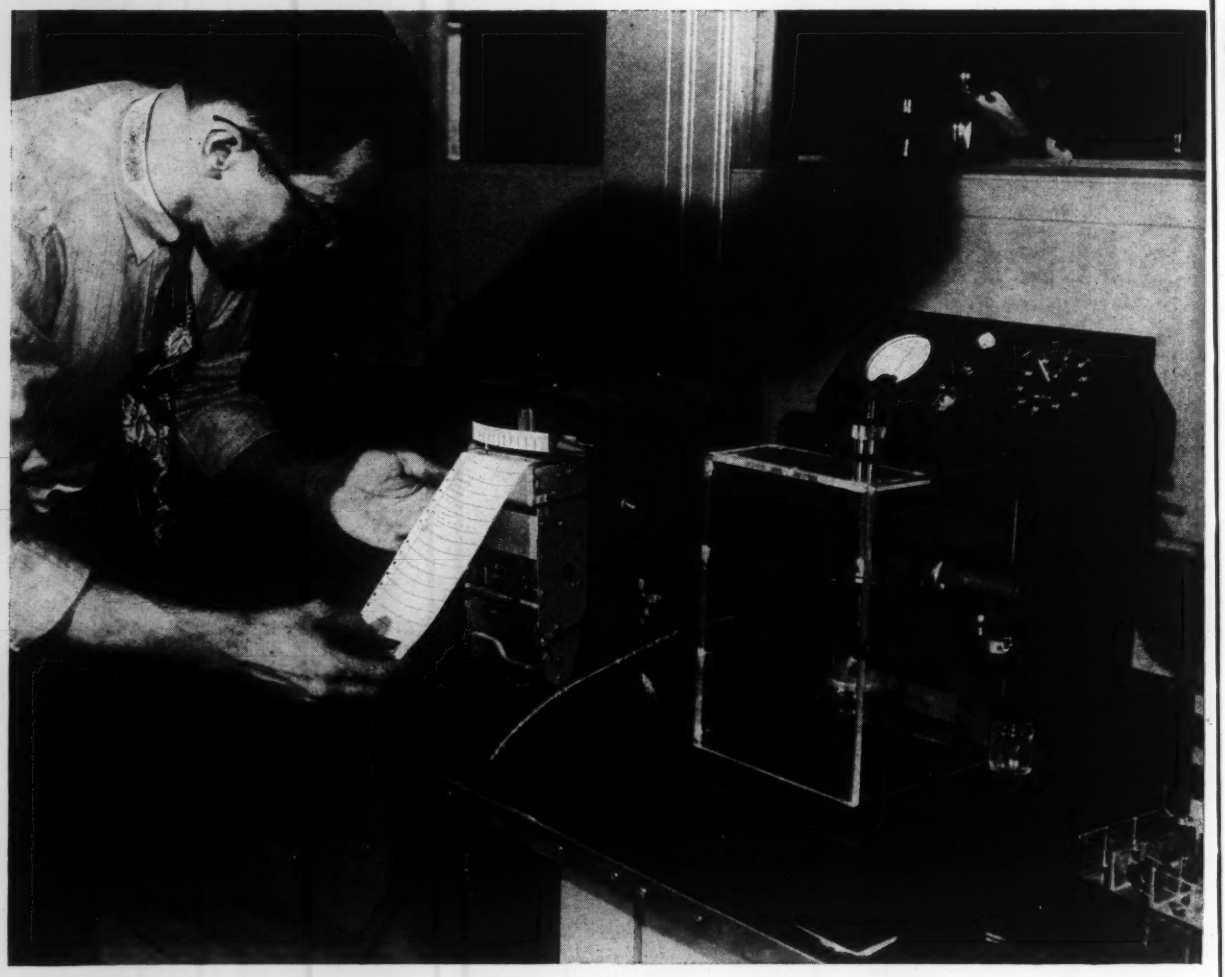

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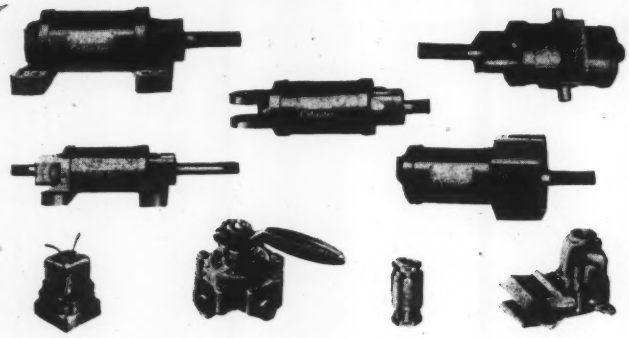

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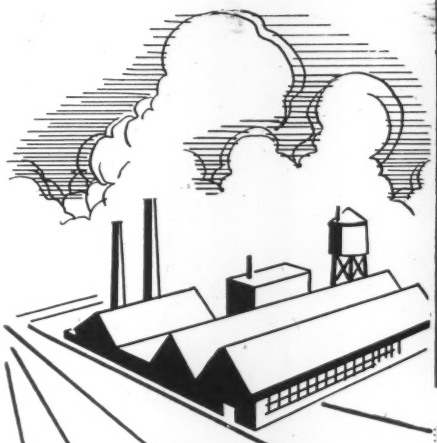

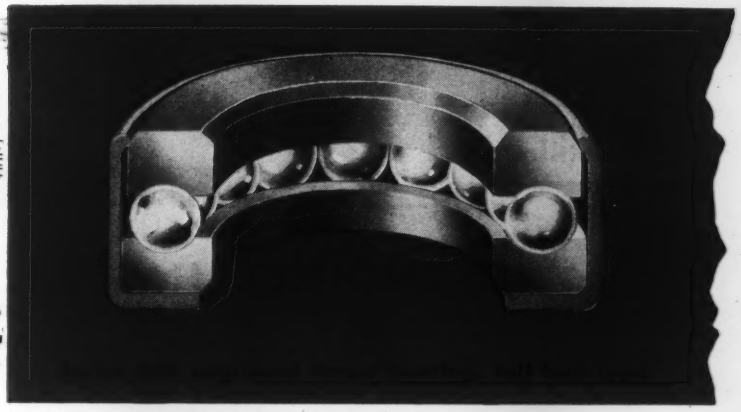

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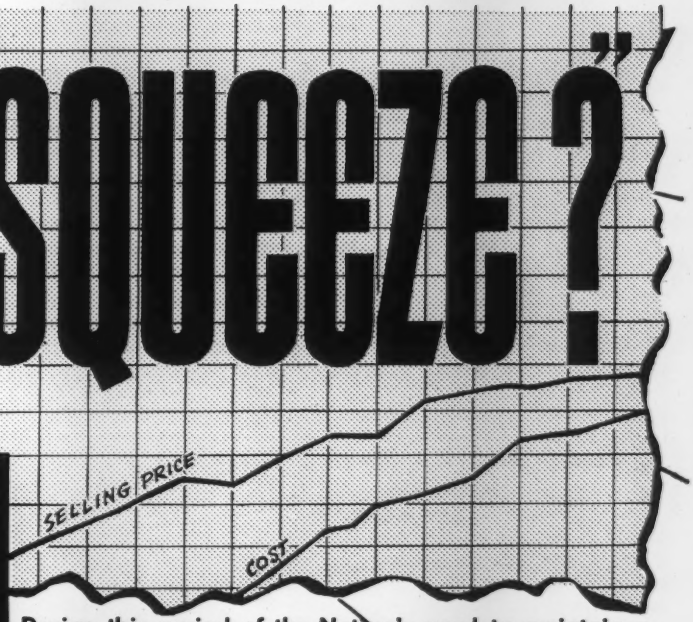

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MACHINE DESIGN TOPICS

. . . IN ENGINEERING AND RESEARCH

Solid Glass Lubricates Hot Steel

Solid glass, which becomes liquid and acts as a lubricant at high temperatures, is used in the Ugine-Sejournet process of hot extruding steel. Plate glass, woven or fibrous glass, according to Jerome Strauss of Vanadium Corp. of America, protects dies from contact with the hot steel and insulates them from excessive heat. Some kinds of steels and "superalloys," difficult to roll, as well as certain shapes hard to roll economically, are being hot extruded by the new process.

Recommendations for Tropical Equipment

A 4-year test of Navy communications equipment in the Panamanian jungle reveals that treatment with fungicidal varnish neither prolongs the life nor increases the reliability of treated equipment. Recommendations for designers of military electronics equipment include: the use of high-quality materials for maximum resistance to physical deterioration; elimination of natural-fiber, cotton and cellulosic plastics; development and use of flexible glass-to-plastic bonding cements; and protection of ferrous parts with pigmented finishes in addition to other surface treatments.

Pump With No Moving Parts

Developed to pump large quantities of liquid metals at a high flow velocity, an electromagnetic pump built at the Argonne National Laboratory has no moving parts. Copper bars are soldered to opposite sides of metal tubing; inlet and outlet pipes are attached to the tubing; and the assembly is placed between poles of a dc electromagnet. Magnetic flux passing through the liquid develops a longitudinal thrust in it.

Transonic Wind Tunnel Based on German Design

Employing a 19-foot double fan with contrarotating blades, a transonic wind tunnel to be completed by the Navy in early 1953 is based on a design partly built by the Germans near Munich and seized by the Allies in 1945. Models can be tested at speeds up to 900 mph in the 574-foot closed-circuit tunnel. Construction is of reinforced concrete, with a steel test section, a cooling tower and a complete air drying system.

Rocky Road from Engineering to Management

A recent survey of 350 companies employing about 50,000 engineers shows that only 34 per cent have any planned information program to prepare engineers for management leadership. According to the National Society of Professional Engineers, who conducted the survey, this poor communication between engineers and top management is causing an estimated loss of 60 per cent of potential managerial talent among engineers.

Ordinary Box Strapping Saws Stainless Sheets

A new toothless sawing method, using steel box strapping, has proved to be a cost-saver in sawing stainless steel and other high-alloy sheets. Friction sawing, literally "burning" through a metal, has been known for

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TOPICS

some time, but band-saw blades have been used on the theory that the tooth spaces acted as tiny air scoops which speeded burning by bringing oxygen to the metal being cut. Solar Aircraft Company now reports that ordinary box strapping hardens and roughens within the first few seconds, allowing the toothless blades to cut as well as or better than band-saw blades at high speeds. In a series of tests, ordinary saw blades lasted less than 2 hours on the average. Strapping, costing 3 per cent as much, lasted up to 29 hours. Toothless spring-steel blades, also tested, had a life up to 70 hours and cost 17 per cent as much.

Soft Drink Lubricates Taps and Drills

Rather than quenching the thirst of tired plant workers, a cola drink is being used in the plant of a West Coast aluminum fabricator as a tap and drill lubricant for high silicon-content aluminum alloys. According to the Alcoa *News-Letter,* everything from peanut oil to whale oil had been tried, with tap and drill casualties continuing unabated. An accidental spill doused the part being machined with the cola drink, resulting in a neatly machined casting to precise tolerances, an increase in drill and tap life of several thousand per cent—and an empty soft-drink dispenser.

Combat Camera Shoots Fast, Uses Built-In Knife

One of the most savage military gadgets yet reported has been developed by the Signal Corps. A new lightweight combat camera is a fast shooter —10 exposures in 5 seconds—and uses a built-in knife to "decapitate" and remove any exposure before the complete roll is shot. Among the camera's less aggressive proclivities are the ability to take 1/500-second exposures and to adjust its combined viewfinder-rangefinder automatically for use with either a 4-inch *f*2.8 lens, a wide-angle *f*4.5 or an 8-inch *f*4. The entire outfit, including camera, carrying case, lenses, filters and flash, weighs only 22 pounds.

New Lacquer-Thinner Formulas Can Replace Hot Spray

"Most of the desirable results obtained with the use of hot lacquer" can be accomplished with new lacquer-thinner formulations, according to W. D. McMaster of General Motors. The new thinners use low-boiling diluents which evaporate between the time that the spray leaves the gun and hits the work, and high-boiling solvents which help the lacquer "flow" slightly after being applied. Virtues claimed for lacquers using the new formulations are: improved surface finish, less polishing, and fewer coats.

Atomic Reactor Operates Under Water

Submerged in a pool of water 20 feet deep, 20 feet wide and 40 feet long, a "low-cost" atomic reactor at the Oak Ridge National Laboratory is being used in the development of improved reactor shields. The entire project cost only $250,000, relatively inexpensive for nuclear reactors, of which $58,400 was for the actual reactor core. Having a continuous full-load power rating of 10 kilowatts, the reactor is an assembly of fuel elements on an aluminum grid, suspended in the pool from an aluminum "bridge" which can be moved along the length of the pool. A second bridge carrying test instruments also spans the pool.

Aircraft Radar "Maps" Terrain

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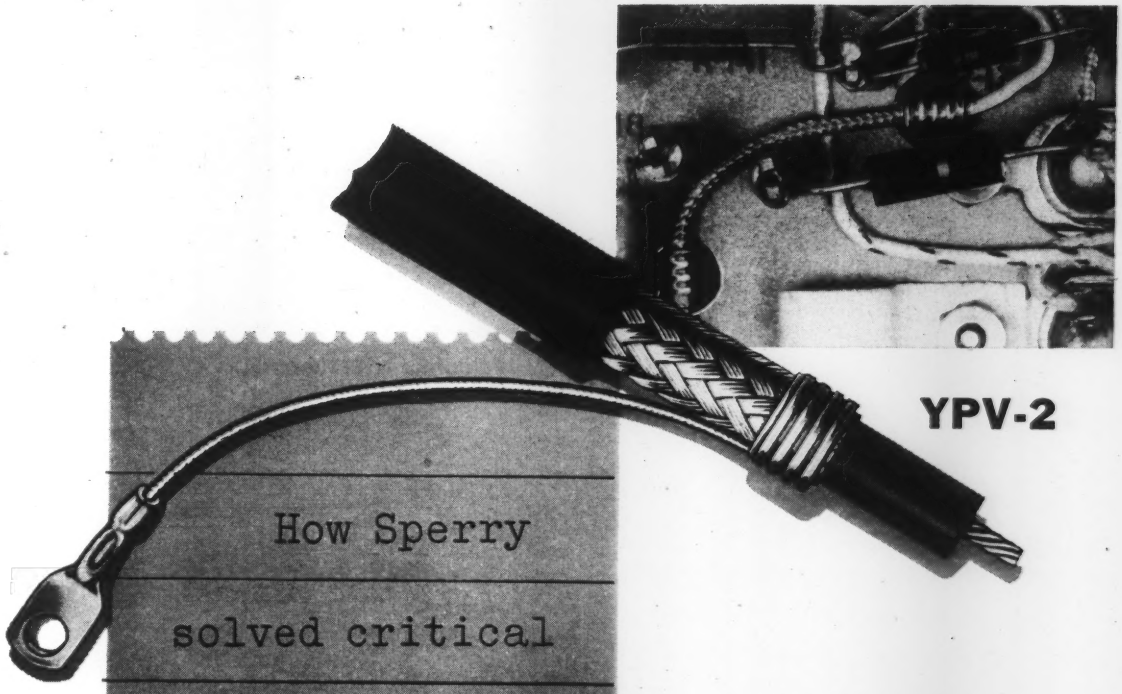

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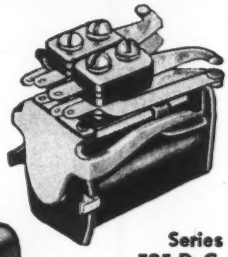

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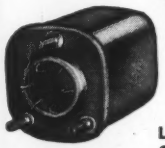

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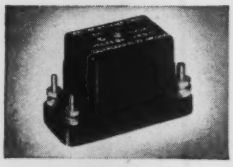

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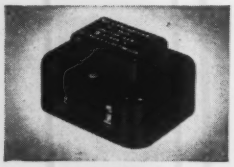

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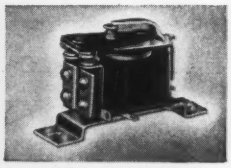

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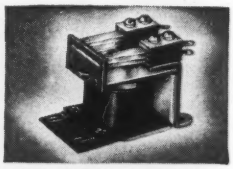

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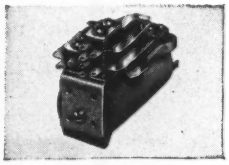

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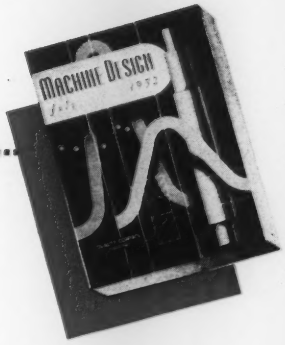


Practical Dreamers!

WHENEVER the term "quality control" is mentioned in design circles, it is likely to be associated solely with inspection and shop gaging. Although it was there that statistical quality control methods first found wide usage in manufacture, today the prospects are more far-reaching and broad. Their true significance and value will only be realized when these basic principles are brought into the engineering department to form a vital link in the design procedure—as a reciprocal producibility requirement.

Where do quality control methods fit into the design picture and why should they be considered? First they define the minimum and the economical limits of accuracy to be expected of production processes and thereby establish the real design tolerances. Secondly, they emphasize and document the need for full understanding by designers of practical gaging and inspection methods required in manufacture. Since demand for design producibility will continue to increase, certain knowledge concerning the capability of processes and the specification of practical measurable limits is a "must."

To promote a better understanding of these methods, MACHINE DESIGN requested Dorian Shainin of Hamilton Standard Div. to prepare an integrated series of articles concerning all phases useful in design. An outstanding authority on quality control, Mr. Shainin has reduced this science to practical, everyday terms for ready assimilation and use. Here, beginning with this issue, are the specifics for enhanced production; for improved machine functioning; for reasonable and economical tolerances; for practical, effective gaging. But, most important, here are the means by which design engineers can remove once and for all the long-time stigma of being termed impractical and unreasonable dreamers!

H. L. Dolz

ASSOCIATE EDITOR

QUALITY CONTROL M

Part I–What Is SQC?

By Dorian Shainin
Chief Inspector
Hamilton Standard Division
United Aircraft Corp.
East Hartford, Conn.

Statistical methods developed originally for production quality control today have wide implications in design. To better understanding and aid adaptation toward improving design results, this series of articles will cover both general aspects and areas of special significance to machine designers.

HOW often has the engineering department been confronted with the statement, "Competition is holding down price rises. I've heard reports of better deliveries by two weeks, and their product is now sticking—suddenly no rejections at all. We stand to be edged out of future orders from at least four mutual customers!" If you begin to hear such rumblings, perhaps it is time to look into the possibilities of and design solutions available with statistical quality control (SQC) methods.

This road has just been entered or is being successfully traveled by about 5000 companies—and you may name the type of industry. While this series of articles will be aimed at the machine designer, much of the material is basic and will also serve to introduce SQC as a vital production and inspection tool of key importance in obtaining desired design end results, *Fig.* 1.

SQC is a logical set of methods designed for application to the processing problems of any industry. The learned statistician or mathematical expert is frankly not the man to have around on the floor introducing quality control, selling it or making it work. Neither is the "Bull of the Woods" expected to be in

Fig. 1—The Lot Plot Meth od, now used by many com panies, is a sampling meth od that actually gives mor accurate results than 10 per cent inspection

METHODS—*Their Use in Design*

the mood long enough to absorb patiently the reasoning behind the laws of probability that explain the "do's and don'ts" of the practice of industrial statistical techniques. Instead, one or perhaps two men with some shop experience and preferably with engineering training are best suited to help put over a working program. These men must be the kind who get along well with other people even under trying circumstances.

Next most important is perseverance. Two men are suggested because in the majority of concerns your associates, who can help but will not, throw up a wall of inactivity. Yes, I suppose you could say, "misery loves company", but it will also be true that two heads are better than one when it comes to discussing the technical aspects of rational subgrouping, how often to take readings, what variables to balance and what to randomize, and so on.

If the right two men are picked, they will be able to shake hands some day and say, "Well, it finally took. Production is using it on those operations that were troublesome, Inspection is working well with sampling, and even Engineering is using statistical methods to determine the true performance differences among alternate schemes." Then the design engineer can enjoy a new freedom of activity that will permit schemes previously considered impractical. He will properly originate situations that take real advantage of the benefits of scientific process control.

Basic Principles: SQC works in process control because it admits a basic truth. All operations characteristically have built-in variables. So, it is impossible to make two things exactly alike. If they seem to be so, a finer, more sensitive method of measuring will always bring out the difference. The situation is part of any process.

The total, built-in variation is a stable one because the results can be counted on to vary, in the long run, equally as much above a fixed average value as below it. Next, a measure of the width of the inherent variation will be a fixed amount. A pattern of the stable variation looks like the distribution curve of *Fig.* 2 when the characteristic or property being measured is plotted along the horizontal axis and the vertical axis shows how often each value is found. The relative measure of the width of the variation is called the *standard deviation* (indicated as the lower case Greek letter sigma, σ) and is expressed in units of the characteristic being measured. The distance of one standard deviation extends from the average value to the point of inflection of the curve—that point where

Fig. 2—A typical normal distribution curve of values about the mean average

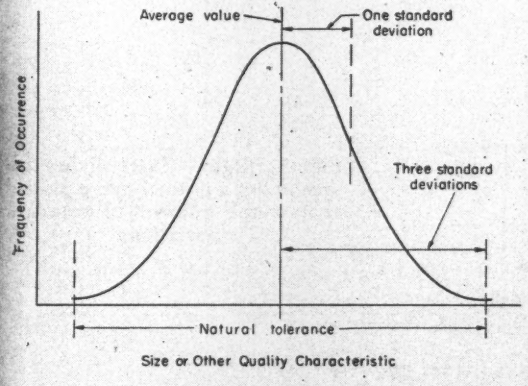
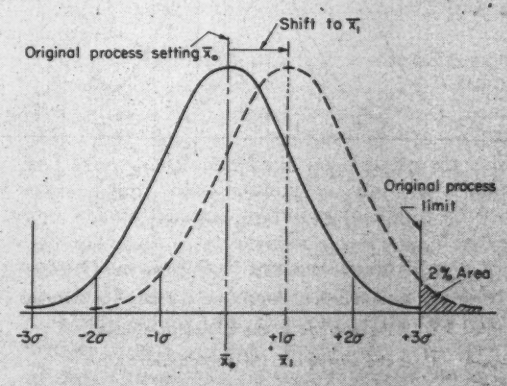


Fig. 3—Cross-hatched region on this chart furnishes evidence that the average value has moved



it changes from a convex to a concave sloping curve.

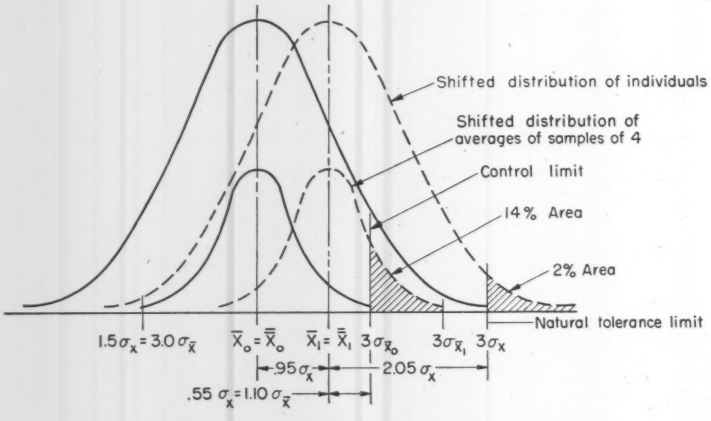
Now these variables, through pure chance, sometimes combine so that their results are completely cancelled out, and the item of product ends up at the true or average value of the process, namely, where it was intended to be. Also by chance, these variables sometimes add in an adverse manner to result in a product that measures at a higher value than intended or, in the opposite direction, a lower value. The relative frequencies of these higher and lower values are defined by the shape of the curve. The frequencies fill out to a distribution called *normal* when variables of equal strength combine at whatever values they take by chance.

It is useful that the area included within plus and minus one standard deviation of such a normal distribution is fixed. It enables the prediction that about two-thirds of all the output of the particular process will be contained within these limits. About 95 per cent of the values to be expected will fall within plus or minus two standard deviations of the average; and plus or minus three standard deviations will include 99.7 per cent of the output. Because it will not pay to set any further bounds to include the remaining three per thousand, this six standard deviation spread is customarily called the *natural* tolerance of the process or its capability.

The Shewhart Control Chart: Some 25 years ago, Dr. W. A. Shewhart of the Bell Telephone Laboratories wrote that a chart might be devised with boundary lines of this type. The chart would permit an operator to reason, when a unit of product was measured and found to fall *within* these limits: "There is no evidence at the moment that any change in the process has taken place, this result being one that conceivably could have occurred by pure chance from a process set as desired. At least that will be true three times in a thousand at the limit lines and even more often when the measurement falls a distance in from the limits." On the other hand, if a reading lay outside the limits, the operator would know that while it could have occurred by chance from an unchanged process, it would happen only less often than three times in a thousand. He could well assume that the process had changed; the position of the whole distribution must have shifted in that direction so that the probability that the reading would occur was actually greater than three per thousand.

In *Fig.* 3 is illustrated, by the broken-line distribution, the shifted position of a changed process. The shaded area, in terms of the proportion it represents of the entire area under its curve, gives the probability that a point would occur beyond the original limit. You can see that for a small shift in process setting the chance of its being found might be small, say, 2 per cent. In the long run fifty measurements would have to be made before you would expect to find evidence from one of them that such a change had taken place.

Dr. Shewhart employed a simple mathematical truth to increase the sensitivity of this indication. Instead of plotting the results of individual measurements on the chart, he called for the plotting of averages of successive groups of measurements, for example, four at a time. The mathematical truth is that the distribution of such average values when plotted against their frequency of occurrence will also form a normal distribution. Strangely enough it holds regardless of the shape of the parent distribution of individual values—provided only that such irregular distribution be stable, that is, the four pieces of every sample each be strictly random selections from the distribution of individuals. Every piece must always



σ_x is the standard deviation of the curve of individual measurements.

$\sigma_{\bar{x}}$ is the standard deviation of the curve of averages of the samples.

$\bar{\bar{X}}_o$ is the average of the original averages.

$\bar{\bar{X}}_1$ is the average of the shifted averages.

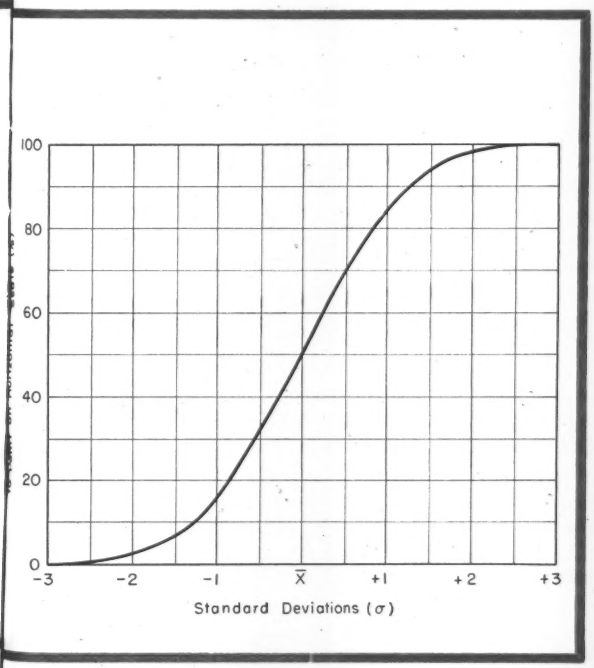
Fig. 4—Left—Sensitivity of indication by means of averages distribution is shown by this chart

Fig. 5—Right—Chart giving the area under a normal curve plotted against the number of standard deviations

have an equal chance to be picked. Now this normal distribution of average values will have a standard deviation that is less than that of the parent distribution, it being smaller by an amount proportional to the reciprocal of the square root of the sample size. For this example of samples of four the square root is two which, inverted, becomes one-half. So the standard deviation of the distribution of averages is one-half the standard deviation of the distribution of individuals. Let us call this *Relation A*.

How this narrowing of the distribution of averages and the use of plus and minus three standard deviation limits for averages as *control limits* increase the sensitivity of the indication is shown by *Fig.* 4. You can determine the approximate amount of the increase by referring to *Fig.* 5. This chart is a plot of the area under a normal curve against the number of standard deviations. Since the curve for individuals in the example has shifted so that 2 per cent of its area is "out of bounds", *Fig.* 5 indicates that the 98 per cent point of the area being within bounds corresponds to 2.05σ from the shifted curve's new average or process setting position. This 2.05σ subtracted from the original 3σ gives the amount of shift, or 0.95σ. Since the average of the distribution of averages will be at the same point as the average for the distribution of individuals, this narrower distribution of averages also had a 0.95σ shift (σ still being the standard deviation for the curve of individuals).

The use of samples of four means that three standard deviations of *averages* will represent the same length as 1.5σ of individuals (*Relation A*). So the area of the shifted distribution of averages beyond its 3σ control limit for averages is (in terms of individuals) $1.5 - 0.95$ or 0.55σ. That figure corresponds to 1.10σ for averages (*Relation A* again). Referring to *Fig.* 5, we find 1.10σ gives an 86 per cent area. That means 14 per cent of the area of the curve for averages will be beyond its original control limit. Where we had one chance in 50 of finding the shift by using individual measurements we now have one chance in seven of seeing it by the use of samples of four taken in succession. A control chart can then be used as a sensitive indicator of a shift in process setting.



Another change of an adverse nature that could occur and about which we would also want to be warned would be an increase in the standard deviation. A control chart obliges by really being two charts. The upper portion controls the averages of successive samples while the bottom chart controls the width of dispersion of the distribution. For sample sizes less than 15, statisticians have found that the standard deviation can be estimated well from the average of numbers called ranges. The range is simply the difference between two measurements, the highest and lowest found in the sample.

While the distribution of the ranges, encountered from taking random samples from a pattern of stable variation of individuals, will not fill out to a normal curve, it strikes close. Also a limit can be computed that corresponds to three standard deviations. It has a related high probability that range values will not be found beyond this limit from an unchanged distribution.

Together as an X and R chart (standing for average and range) these two controls provide a fine method for getting almost any scrap or rework producing process out of trouble, *Fig.* 6. The exceptions to this happy situation do not occur often, and their treatment will be discussed in Part 9 of this series, "Trouble Shooting Machine Designs".

Such charts are useful when the human element stands for some part in the total variation. You can liken the control chart to the pattern of tracer bullets that allows the rifleman to correct his aim. The successive average and range points plotted on the chart show that the machine or process needs to be reaimed when the points start to fall "out of control." On the other hand, their position within the control limits labels such variation as probably inevitable, and no attempt should be made to adjust the process to make up for the fact that points may be above or below a desired exact average position. The indication to leave the process alone helps get an increased production rate and reduces the extra variation caused by a careful operator making too many adjustments.

Because this type of chart records measurements, it is also known as a control chart for *variables*. The term stands in contrast to *attributes*, meaning the parts rate solely as acceptable or not, as you would find from X-ray pictures, go and not-go gages, comparison with color standards, etc. In planning variable control charts, you must be able to devise a new, or employ an existing, method of applying gaging results to a numerical scale. It will also help to have an orderly method of deciding which specifications in the shop should be charted. *Fig.* 7 shows an approach to this problem through a review of the scrap records priced by the accounting department. The horizontal scale of the plot represents the specifica-

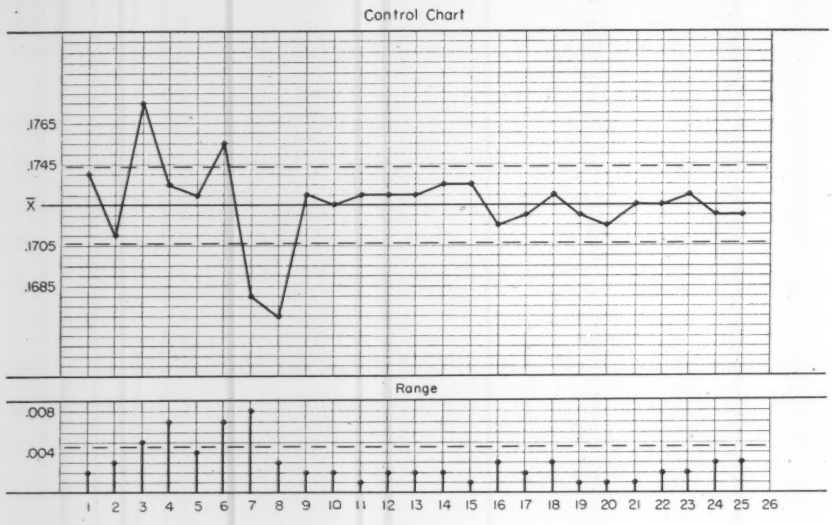


Fig. 6—A typical average and range control chart used in production control

tion values that were exceeded and that led to the parts being scrapped. The vertical scale pictures the accumulated cost of the scrapped parts for a given calendar period. The arrangement from left to right adds the scrap for the first specification to the scrap for the next larger contributor to the cost, and that total to the next larger, and so on. You can then drop down from the total cost on the right to a point, say 25 per cent of the way from the bottom (through the shaded areas) and be agreeably surprised. A horizontal line drawn here will indicate that rather few specifications are part of the three-fourths of the total scrap cost. It is these few shop operations that will need the first control charts.

Additional Charting Tools: Two other useful Shewhart control charts some under the heading of attribute types. One shows the variation in fraction defective of lots, usually found from samples of 25 or more parts each. The other keeps track of the variation in number of defects per unit found in given lengths or areas of a continuous product, or in individual and usually complex assemblies. The fraction defective arrangement is called a p chart, and the one for the number of defects a c chart.

Most plants keeping records list the number of items rejected, usually by part number. If you just mark with such data the total number of items handled or inspected, the ratio of the items rejected to the items inspected spells out the fraction defective. Simple graphs to be presented in Part 3 of this series will provide statistical control limits for such data. The limits also will reveal whether the variation being met daily, from batch to batch or what have you, can be expected from pure chance. While the p chart needs more parts processed before enough data are at hand for action, it takes in a greater scope of activity than the $\overline{X}$ and R chart. For example, under certain conditions the quality of all specifications together for a given part or even the quality performance of a whole department or plant can be watched. Out of control points give clues as to where the more sensitive $\overline{X}$ and R chart might be needed awhile to fix the particular specification that is now a larger part of the high fraction defective.

A smaller fraction defective than would be expected by chance would be taken generally as a definite sign that an improvement had been made to the process. While possibly so, it is always well to check first whether such points may be due to a lowering of inspection standards.

A c chart can pertain to the number of pinholes per piece of coated articles, the number of defects per X-ray picture of sets of ten castings, the number of imperfections per finished rug, the number of defects for each five yards of wire, etc. The chart also applies to complicated units where, in any one assembly, there is great room for defects of many types. Here each point on the control chart represents the total number of defects of all categories found for each unit. Getting the values of the control limits and the interpretation of the chart will also be covered in a later part of this series.

Sampling Plans: Tools for statistical quality control of production material fall under two main headings—control charts and sampling plans. Sampling plans are also based on the laws of probability. Their goal, as contrasted to the direct control of a process in operation, is to provide an economical means of inspecting finished product that is usually available in the form of one or more lots. The better known sampling plans are schemes, using the attribute method, that say that a sample of certain size from a given lot should reject the lot only if the number of defective items found exceeds a certain allowable figure. As

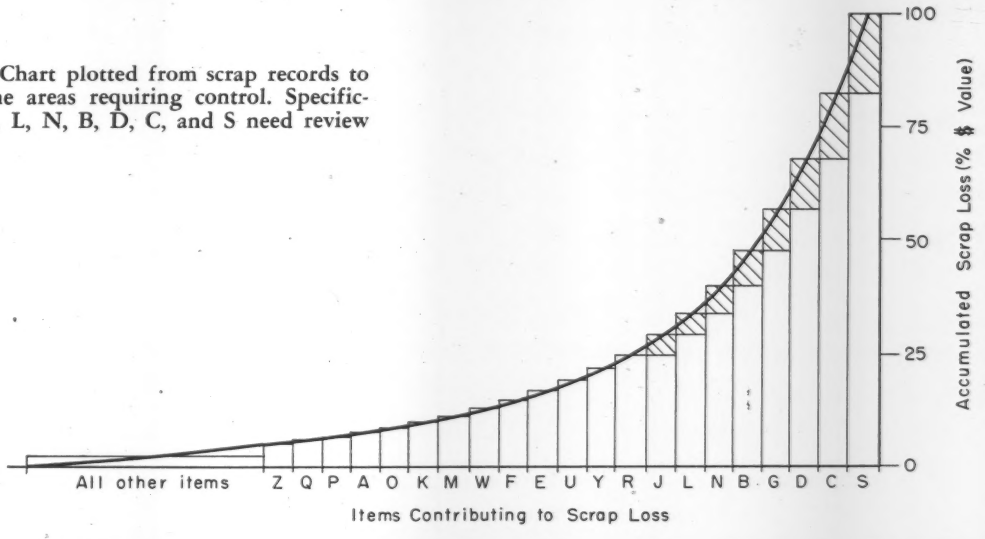


Fig. 7—Chart plotted from scrap records to determine areas requiring control. Specifications J, L, N, B, D, C, and S need review

described to this point, the sampling plan furnishes no known protection in terms of the maximum per cent defective that might get by the plan in the form of single lots or even in the long run. However, such plans do have a large and definite probability (some number short of 100 per cent) of rejecting lots of a given undesirably high per cent defective; and another high known probability (also less than perfection) of accepting lots of a particular value of low per cent defective, which you would have no qualms to use. These fixed values of per cent defective are only of theoretical interest since material only seldom is received for sampling, just that degree defective.

When a rule is added to this sampling scheme about the treatment of the rejected lots, then a limiting protection in the form of a maximum per cent defective can be reached in the long run. The rule is: rejected lots must be screened or checked 100 per cent, and all the defectives must be removed and replaced by good pieces. All material entering the storeroom from such a sampling procedure then consists of: (1) lots that produced samples that had no more defects than allowed by the plan and (2) lots that are not defective at all because they produced the samples that were rejected and the lots were screened. So, in the long run, the mixture will be diluted by the screened lots, reducing the net per cent defective of the entire group. Certain lots might have produced a reasonably good sample in spite of a high per cent defective, according to the laws of chance. But such lots cannot continue to do so and the presence of the few of them that get by cannot increase the per cent defective of the storeroom mixture beyond a calculated limit.

Other versions of this sampling plan give a lot a second chance or, in still other types, several more chances before it is decided that the lot needs screening. These additional reprieves are granted if the number of defective parts found in the first or early samples is larger than a specified number that would permit immediate acceptance of the lot. At the same time the count of such parts must be less than another but larger number that, if exceeded, would mean "sudden death" in the form of requiring the lot to be screened without further sampling. Inspectors get certain psychological benefits from the confirmation of successive rejections that sometimes come from the use of these double or multiple (sequential) sampling plans as against the single sampling deal. Also such multiple sampling plans usually result in less total inspection when the per cent defective of the incoming material is quite less than the limiting value allowed by the selected plan. Their complexity of administration, however, may tend to offset such expected advantages. Some other disadvantages of many forms of attribute sampling will be described in "The Human Element in Inspection" (Part 5).

Just as control charts for variables and for attributes are useful for different statistical control tasks, these attribute type sampling plans have contemporaries of the variable type that are more involved but give new benefits. The protection against accepting defective material is increased markedly, or for much smaller sample sizes you can operate at equal risk levels. It is too bad that some sampling situations cannot be handled by variables because of the impossibility of taking readings.

When the inspection or testing requires the destruction of the articles, a sampling plan by variables is understandably attractvie, if not an economic necessity. Later in this series of articles, the choice of risk levels and operation of such a special plan will be detailed.

The attribute type sampling plans and variable ones for destructive inspection are designed to give quality assurance as defined by picked numerical values of

risk. None of the samples pretends to give an acceptable degree of assurance concerning the true per cent defective of the particular lot that was sampled. In other words, these plans operated in the long run to give the selected degree of assurance. Many lots of similar material must be sampled in order to let the laws of chance work to accept most of them if the per cent defective is running well below the selected risk level; to reject a fair portion of them if the per cent defective is running close to the risk level; or to reject most of them when it is running somewhat beyond the level. There is a special sampling plan by variables that does provide a remarkably accurate estimate or picture of the true condition of the lot being sampled. It is called the Lot Plot plan and was developed at the Hamilton Standard Division of United Aircraft Corporation as a means for improving upon the results of 100 per cent inspection of critical items. It has been successful to the extent that over sixty other concerns have already adopted it to date.

Finally, there are types of sampling plans for continuous production. The continuous plans apply when, instead of stopping as fixed lots, material goes by in a steady or broken stream as if on a conveyor belt. The recently developed Lot Plot method, along with sampling plans for continuous production both by the attribute and variable methods, will be analyzed and will be compared with the strengths and weaknesses of 100 per cent inspection.

Limits in Production Quantities: A question which logically arises concerns the minimum amount of production necessary to obtain the available benefits. The guide in the following can be used as the smallest number of individual items that have to be processed to begin to estimate control-limit positions, etc., to interpret results. A neat feature is that the rate of material production is not important. The critical thing is just the number of pieces, lengths, batches, assemblies, etc., that are made.

An $\overline{X}$ and R chart needs thirty successive parts, ten subgroups or samples of three each, to allow a first guess of the control limit positions. They should be confirmed or adjusted to their more correct positions after at least 75 parts are measured. A p chart can start to work with ten subgroups of 25 parts each or a total production of 250 parts if the material is running not much under 8 per cent defective. Below 4 per cent defective means about 500 pieces arranged in ten subgroups of 50 would be in order. A special technique to counteract this dependence of minimum quantity upon per cent defective will be explained in this series.

A c chart can work with as few as ten or fifteen assemblies, lengths, or areas if some defects are found in each unit checked. Acceptance sampling by attributes pays only when the per cent defective of the incoming material generally runs less than the picked risk limit, else the results would too often call for 100 per cent screening. Since such sampling plans give long-run quality assurance, at least ten separate sample lots are needed in, say, the length of time it normally takes for stock turnover in a plant. Splitting up some lots before sampling may thus be necessary. Only then can you feel that the probabilities selected are controlling the quality level found by your customers. The Lot Plot plan will operate well with a single lot, and it will also be economical when the lot size is greater than 150 pieces.

Radioactive Cobalt Detects Steel Defects

AMONG the first practical industrial applications for nuclear fission is the examination of steel castings for internal defects with radioactive cobalt. Irradiated in a nuclear reactor at Oak Ridge, the "pill," an ampoule of radioactive cobalt wire, sends out powerful beta and gamma rays. The gamma rays are capable of penetrating steel from ½ to 6 inches thick. When used with photographic film, the rays produce a picture of any defects in the steel.

Advantage of the isotope is its relatively low cost compared to radium, and its ease of application. At Empire Steel Castings Inc. the radioactive wire, mounted in a circular holder, is elevated over the casting by means of a cross-arm attached to an ordinary laboratory stand. Height of the ampoule from the steel is determined by thickness of the steel, with exposures ranging from ½ to 6 hours.

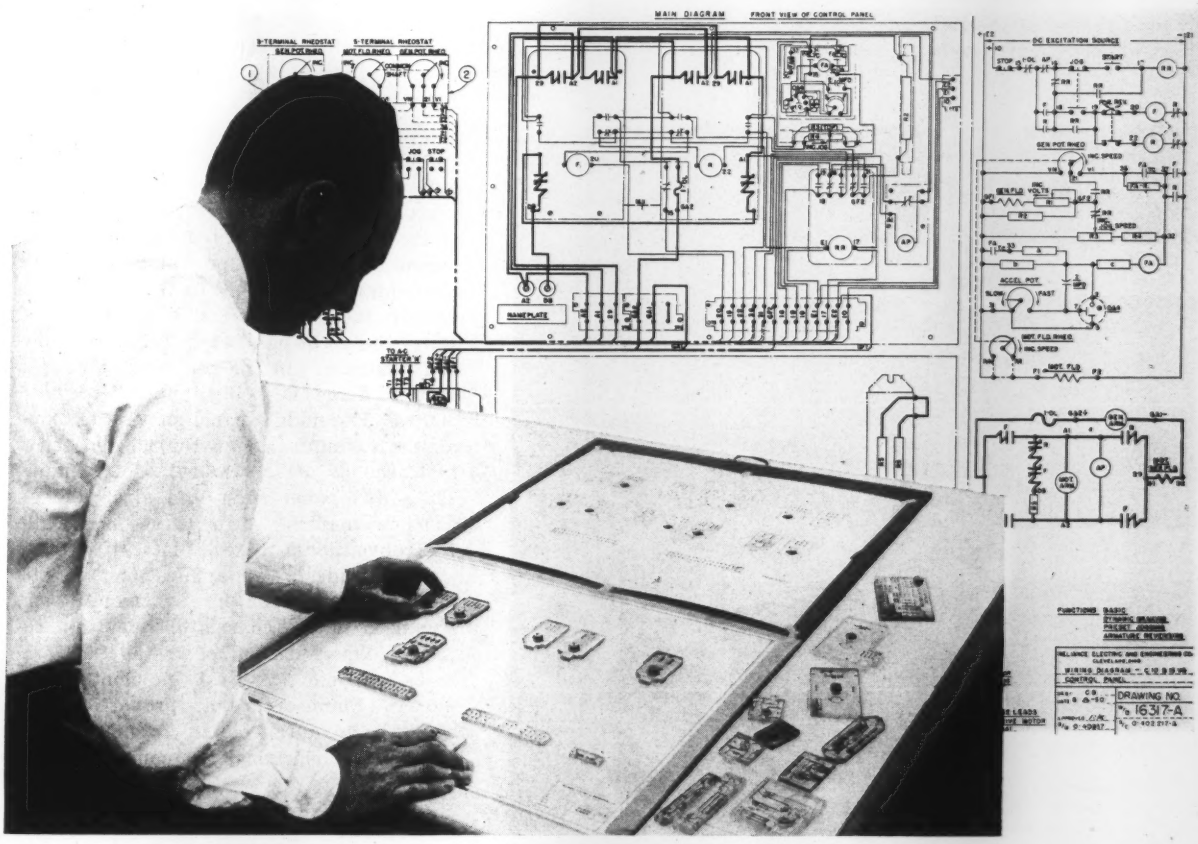
According to Empire, the isotope has a distinct cost advantage over radium, with the ampoule costing less than 2 per cent as much as a comparable amount of radium. The unit has a half-life of over five years, but can be used with diminished efficiency for up to ten years.

SCANNING the Field For Ideas

Template drafting, below, used where standardized components are drawn repeatedly, has increased the efficiency of draftsmen at The Reliance Electric and Manufacturing Co. by as much as 30 per cent—with a similar saving effected in time. Each template contains a scale drawing on a transparent plastic, representing a standard component such as a switch, relay, contactor, or terminal block.. Permanent magnets hold the units in position on sensitized paper over a metal drafting board. When the proper arrangement is achieved the sensitized paper is exposed and developed. Transparent sheets containing borders, titles, notations,.etc., can also be imprinted on the drawing paper at the same time.

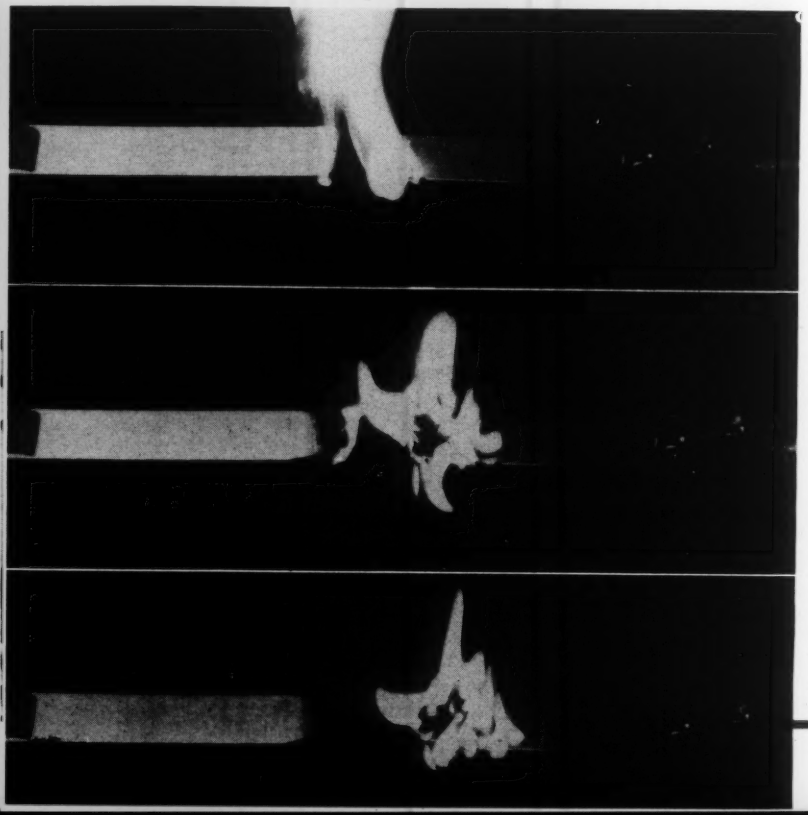
All the draftsman does to complete the drawing is to add the necessary connecting lines to finish the control panel, switchboard, or wiring diagram. If his arrangement is not satisfactory, it is a simple matter to spot the templates on another sheet, making as many sheets as necessary until the best configuration is obtained.

In addition to saving time in planning and drafting, human errors are eliminated in that each template is reproduced accurately, and in complete detail, every time it is used. There is no need to check the accuracy of the drawing of any component after the original accuracy of the template has been checked. Also, care and skill required to make a conventional layout are not needed, as the templates are scale drawings of the parts involved. Proper clearance between components becomes automatic.



Ideas

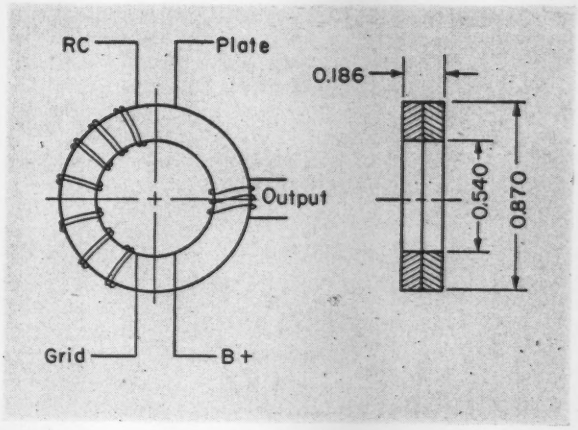
Surface roughness may be measured easily with the simple, portable gage illustrated above. This instrument is capable of detecting scratches as small as one-millionth inch and is useful for checking the surfaces of mating parts and other components where minute surface irregularities may cause difficulties. The pickup head of the instrument contains a diamond stylus which is moved over the surface of the part to be measured. An electronic pickup and high sensitivity transducer translate the motion of the stylus into electrical voltages which are read on the instrument dial in terms of roughness. Recently developed at the General Motors Research Laboratories the instrument may be plugged into any convenience outlet, making surface-roughness measurements a simple shop operation with this gage.



Flame-retardant plastic laminates, employing special resin formulations, provide increased safety in electronic, aircraft and other equipment. Incorporation of the flame-retardant feature has no detrimental effect on punching or other machining properties. In the test panels at left, the new material is the left-hand strip, the right-hand strip being a standard laminate. In the top view, a bunsen burner flame is being applied to both strips. The middle panel shows the flame almost extinguished on the new material two seconds after removal of the flame. The third panel shows no afterglow on the new material after 19 seconds while the conventional material is still burning.

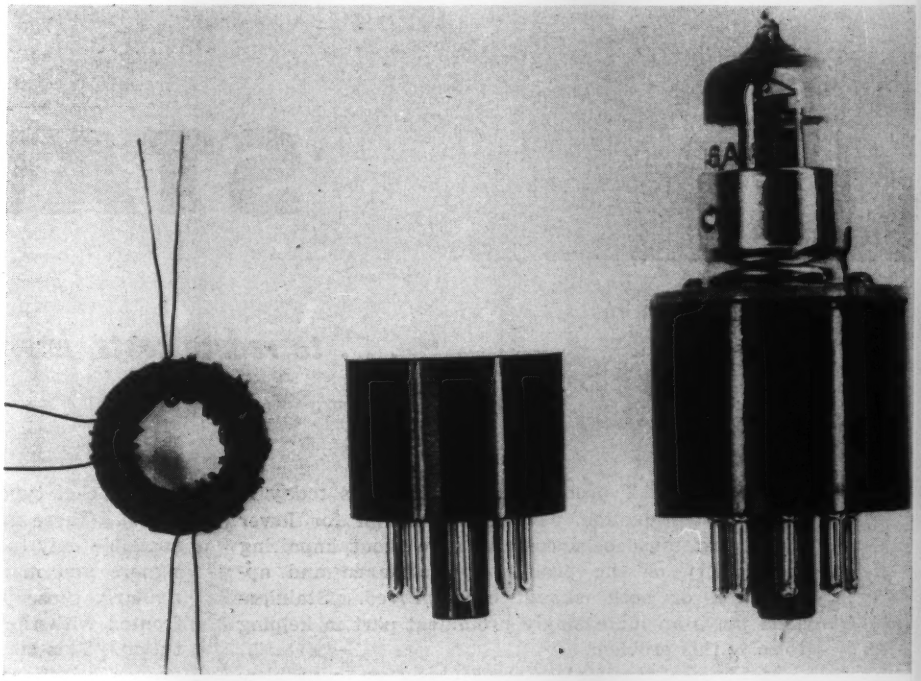
First widespread application of this laminate, developed by Synthane Corp., has been in the chassis of television receivers where sheets of metal-clad laminate are employed in printed circuitry. Flame-retardant properties also would be advantageous in circuit breakers and similar electrical components.

Fast response pulse transformer, right, used for triggering, switching and timing functions in electronic equipment, is unusually simple and inexpensive. It consists of a few turns of wire wound on a small ferrite ring. Designed by Carroll Tschiegg of the National Bureau of Standards, this transformer has a 0.02-microsecond pulse rise when employed in a conventional blocking oscillator circuit and is being used in a timing system for measuring the speed of sound in liquids. This rise time is about twice as fast as the fastest transformers having thinly laminated steel cores.

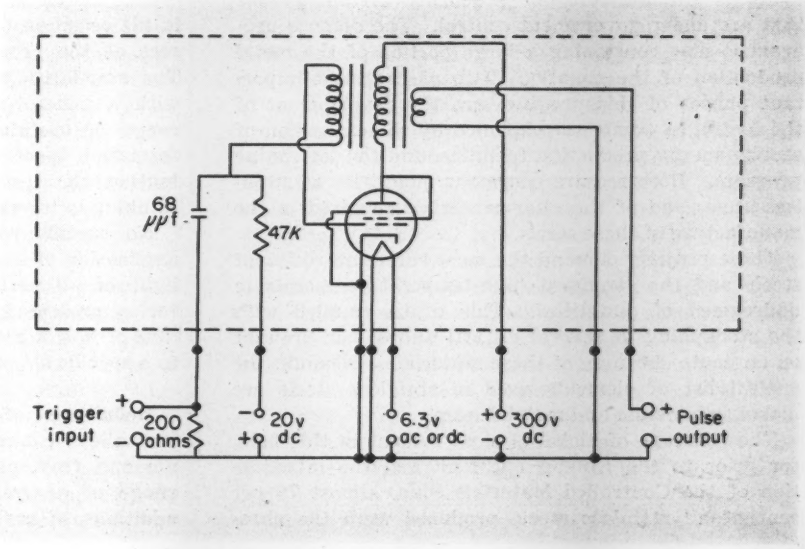


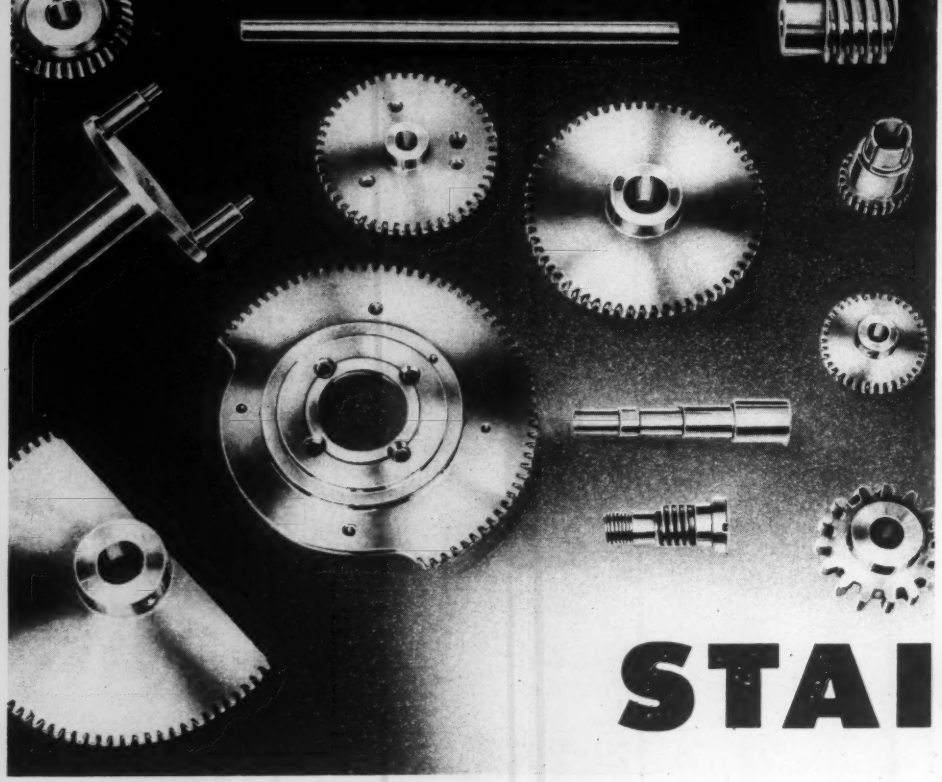
Superior characteristics of the new transformer are due largely to its ferrite core. Resistivity of the nonmetallic magnetic material is high enough to give low losses as well as high permeability, even without subdivision of the material. The core, made by cementing together two standard toroids of a commercially available ferrite, is less than one inch in diameter and the plate, grid and output windings consist of 13, 12 and 6 turns, respectively, of No. 24 enameled copper wire. The plate and grid windings are wound together in a single layer on the ferrite ring.

When triggered, a blocking oscillator — being a transformer-coupled feedback oscillator — produces a single rectangular voltage pulse having a fast rise and fall. The more rapid the pulse rise, the more accurate is the timing. At the right in the illustration, is shown a complete blocking oscillator using a plug-in base which houses the transformer shown to the left of the oscillator. The schematic circuit for the unit is within the dotted line in the diagram.



Small size of the ferrite core transformer makes it possible to construct complete blocking oscillators as compact plug-in units. They include a transformer, a miniature tube, and a grid capacitor and resistor mounted on an octal base. All leads are brought out to the base pins, allowing for a variety of triggering and biasing methods.





Factors in Selecting STAINLESS

. . . to reduce costs, improve performance, and cons

A PRIMARY problem facing designers today is cost reduction. Naturally, design for lower cost must be accomplished without impairing the quality of the product—performance and appearance, or both, should be improved. Stainless steel plays an increasingly prominent part in helping to solve this problem.

In the use of stainless steels, however, a problem today is the difficulty of procuring certain grades that are under government control. The defense program is now consuming a large portion of the metal production of the country. Two of the most important phases of this program are the development of the hydrogen bomb, accompanied by the expansion of atomic energy production facilities, and the jet engine program. Both require enormous quantities of stainless steels and of the alloy materials required in the manufacture of these steels.

These projects demand the most corrosion-resistant steels and the strongest high-temperature metals in undreamed of quantities. This drain, coupled with the stockpiling of several critical alloys, has brought on an acute shortage of these materials. Heading the critical list of elements used in stainless steels are nickel, columbium and molybdenum.

The shortage of nickel is most evident in this field, for prior to the Korean outbreak and the introduction of the Controlled Materials Plan, almost 70 per cent of all stainless steels produced were the chromium-nickel types containing upwards of 8 per cent nickel. These nickel-bearing stainless steels are now available only for high priority applications. The designers and manufacturers of metal products, particularly those producing nondefense items, are confronted with the problem of down-grading or substitution. This situation places special emphasis on the proper selection and application of stainless steels.

This article is presented as a guide to the designer in his selection of stainless steels—both to reduce the cost of the product and to conserve critical alloys. The standard types of stainless steels are reviewed with a general discussion of their properties, their range of usefulness, and their limitations. The information is of a descriptive nature to bring to attention the lesser known grades and to stimulate thinking in terms of the less critical alloys.

No specific recommendations are made, for each application of stainless steel must be appraised in the light of all pertinent factors. Illustrated case histories presented throughout this article give some idea of how a particular stainless type can be adapted to a specific set of requirements.

Definitions: Stainless steels are broadly defined as iron alloys containing from 12 to 30 per cent chromium and from nil to 20 per cent nickel. This basic range of analysis is further modified by controlled additions of carbon, molybdenum, columbium, titan-

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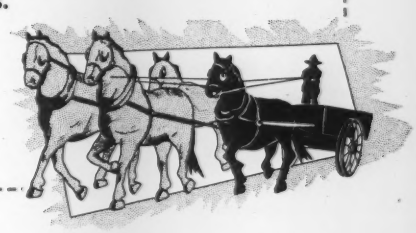
STEELS

...stical alloying elements

DESIGNERS striving to improve products find advantages in applying stainless steel. But with a choice of more than 30 different grades, one finds it all too easy to select a stainless grade richer in alloy than necessary. Thus, using a four-horse team for a one-horse load may increase costs. Equally important, it can well introduce problems of procurement because of today's shortage of several alloys. This article outlines and compares the distinguishing properties of stainless steels as an aid to the designer in his evaluation of their properties for his planned applications—and in his reappraisal of current specifications.



ium, selenium, sulfur, copper, aluminum, and other elements. These minor elements each contribute specific effects, either to control mechanical properties or to improve corrosion resistance.

The corrosion resistance of stainless steels is attributed to a surface phenomenon—passivity—which involves the formation of a protective film on the surface of the metal due to the action of oxygen. This dense, tightly adherent, invisible film of chromium oxide serves to protect the underlying metal from progressive oxidation or rusting in the atmosphere and to retard attack under more severe corrosive conditions. When exposed to environments which support the formation of this passive film, the higher alloy stainless steels are truly stainless, maintaining a bright, tarnish-free, dimensionally stable surface.

The ability to passivate is principally a function of chromium content. The addition of chromium to iron produces a gradual improvement in rust resistance until at approximately 12 per cent chromium, the alloys acquire the ability to spontaneously "passivate." Corrosion resistance reaches a maximum at approximately 18 per cent chromium although additions up to 27 per cent contribute to improved oxidation resistance.

The introduction of nickel to the chromium steels enhances their ability to passivate and markedly increases their corrosion resistance, particularly pit corrosion. This effect is fully realized at approximately 8 per cent nickel. In like manner, the addition of molybdenum to steels containing chromium and nickel further increases resistance to corrosion by strengthening the protective film.

Carbon, on the other hand, counteracts the effects of chromium by combining with it to form chromium carbides, thereby reducing the quantity of chromium available for corrosion resistance. In many of the steels carbon is held to a minimum as an impurity; however, as will be explained, it is added in certain classes for improved mechanical properties.

All told, there are approximately 30 standard stainless steels, each of which is designed to fill a specific need. The composition limits of these standard types are shown in TABLE 1. Knowledge of each of these grades gives the designer opportunities to utilize the best stainless grade in a specific product. Here, too, is real opportunity to upgrade quality while reducing costs.

To simplify selection and to facilitate an under-

standing of this family of metals, they have been arranged in three basic groups:

GROUP A—MARTENSITIC HARDENABLE STEELS: These steels contain chromium and carbon as the principal alloying elements. They respond to heat treatment and can be hardened in a manner similar to that employed with the familiar alloy and tool steels to provide a wide range of mechanical properties. They are magnetic

GROUP B—FERRITIC NONHARDENABLE STEELS: This group comprises the chromium-iron alloys. Like Group A they are magnetic; however, they do not respond to heat treatment and are normally used in the annealed state where they exhibit their maximum softness, ductility, and corrosion resistance. The mechanical properties of these steels can be increased to a small extent by cold working

GROUP C—AUSTENITIC NONHARDENABLE STEELS: The chromium-nickel alloys which form the basis of this group offer a greater degree of corrosion resistance than the steels of Groups A and B. They are strong, tough, and ductile, and although they cannot be hardened by heat treatment, they can be appreciably strengthened by cold working. These austenitic steels are nonmagnetic.

This classification is based on the metallurgical characteristics of the steels; hence, the designations —martensitic, ferritic, and austenitic. However, this teminology need not be confusing. From a design standpoint, the essential fact is that there are three basic groups, each with its own physical, mechanical, and corrosion resisting qualities.

Selection: For a given design selection of the most suitable stainless demands an intelligent evaluation of the requirements of the application. The foremost quality of the stainless steels is corrosion resistance, and corrosion resistance should be the primary basis for selection. A given steel may have just the right combination of mechanical properties for a given job. If, however, it corrodes within several hours, it obviously is not the proper selection for the application.

One must first consider the degree of corrosion resistance required. Where appearance and freedom from discoloration are important or where dimensional stability is desired, the steel selected must be essentially immune to the environment. Complete resistance is also required where the product being handled may not be contaminated by dissolved metals, as in the food, dairy, beverage, and pharmaceutical industries. On the other hand, some equipment can tolerate a predictable rate of corrosion; selection in these cases requires an economic evaluation of the expected service life of the assembly and its components.

Under mild corrosive conditions—such as the atmosphere, fresh water, steam, lubricating oils—the entire family of stainless steel is open to selection. Under more severe corrosive conditions, as in chemical service, the field is confined to those steels which offer useful resistance to the corrodent. There are many published corrosion tables indicating the relative resistance of the stainless steels to various corrosive media. Tables of this type, generally based on

Table 1—Chemical Composition Limits of the AISI Stainless and Heat Resisting Steels

Type No.	Carbon (per cent)	Manganese (max per cent)	Silicon (max per cent)	Chromium (per cent)	Nickel (per cent)	Other Elements (per cent)
301	0.08-0.20	2.00	1.00	16.00-18.00	6.00-8.00	.....
302	0.08-0.20	2.00	1.00	17.00-19.00	8.00-10.00	.....
302B	0.08-0.20	2.00	2.00-3.00	17.00-19.00	8.00-10.00	.....
303	0.15 max	2.00	1.00	17.00-19.00	8.00-10.00	P, S, Se 0.07 min, Mo 0.60 max
304	0.08 max	2.00	1.00	18.00-20.00	8.00-11.00	.....
305	0.12 max	2.00	1.00	17.00-19.00	10.00-13.00	.....
308	0.08 max	2.00	1.00	19.00-21.00	10.00-12.00	.....
309	0.20 max	2.00	1.00	22.00-24.00	12.00-15.00	.....
309S	0.08 max	2.00	1.00	22.00-24.00	12.00-15.00	.....
310	0.25 max	2.00	1.50	24.00-26.00	19.00-22.00	.....
310S	0.08 max	2.00	1.50	24.00-26.00	19.00-22.00	.....
314	0.25 max	2.00	1.5-3.0	23.00-26.00	19.00-22.00	.....
316	0.10 max	2.00	1.00	16.00-18.00	10.00-14.00	Mo 2.00-3.00
317	0.10 max	2.00	1.00	18.00-20.00	11.00-14.00	Mo 3.00-4.00
321	0.08 max	2.00	1.00	17.00-19.00	8.00-11.00	Ti 5×C min
329	0.20 max	...	...	23.00-28.00	2.50-5.00	Mo 1.00-2.00
347	0.08 max	2.00	1.00	17.00-19.00	9.00-12.00	Cb 10×C min
403	0.15 max	1.00	0.50	11.50-13.00	.....	.....
405	0.08 max	1.00	1.00	11.50-13.50	.....	Al 0.10-0.30
406	0.15 max	...	...	12.00-14.00	.....	Al 3.50-4.50
410	0.15 max	1.00	1.00	11.50-13.50	.....	.....
414	0.15 max	1.00	1.00	11.50-13.50	1.25-2.50	.....
416	0.15 max	1.25	1.00	12.00-14.00	.....	P, S, Se 0.07 min, Mo 0.60 max
420	Over 0.15	1.00	1.00	12.00-14.00	.....	.....
420F	Over 0.15	...	...	12.00-14.00	.....	S, Se 0.07 min, Mo 0.60 max
430	0.12 max	1.00	1.00	14.00-18.00	.....	.....
430F	0.12 max	1.25	1.00	14.00-18.00	.....	P, S, Se 0.07 min, Mo 0.60 max
431	0.20 max	1.00	1.00	15.00-17.00	1.25-2.50	.....
440A	0.60-0.75	1.00	1.00	16.00-18.00	.....	Mo 0.75 max
440B	0.75-0.95	1.00	1.00	16.00-18.00	.....	Mo 0.75 max
440C	0.95-1.20	1.00	1.00	16.00-18.00	.....	Mo 0.75 max
440F	0.95-1.20	...	...	16.00-18.00	.....	S, Se 0.07 min Mo 0.75 max
443	0.20 max	...	...	18.00-23.00	.....	Cu 0.90-1.25
446	0.35 Max	1.50	1.00	23.00-27.00	.....	N 0.25 max

Table 2—Group A—Martensitic Stainless Steels

(Hardenable, Magnetic)

AISI Type No.	Carbon (per cent)	Chromium (per cent)	Other Elements (per cent)
403	0.10	12.50	.....
410	0.10	12.50	.....
414	0.10	12.50	Ni 2.00
416	0.10	13.00	S 0.25
420	0.30	13.00	.....
420F	0.30	13.00	S or Se 0.25
431	0.15	16.00	Ni 2.00
440A	0.70	17.00	.....
440B	0.85	17.00	.....
440C	1.10	17.00	.....
440F	1.10	17.00	S or Se 0.25

Analyses are nominal; refer to TABLE 1 for composition limits.

laboratory tests, are intended to serve as a guide in narrowing the field to be investigated. However, these tests cannot duplicate performance conditions, and final selection requires evaluation on the basis of actual service tests. Similarly, in equipment designed for high-temperature service, selection is limited to the alloys that will resist oxidation or corrosion at the operating temperatures.

With the field narrowed to those alloys which provide the required corrosion resistance, selection will then depend on the physical and mechanical requirements of the unit. The choice is a simple one if the corrosion problem is mild, for the thirty-odd stainless steels offer almost any desired combination of mechanical properties. Design ingenuity is needed, though, if the selection is restricted to one or two steels because of the corrosive service anticipated.

The fabricating qualities of the various grades place the third limit on freedom of selection. The proper choice also depends on the method by which the part can be most suitably manufactured. Is it to be forged, cold formed, deep drawn, spun, machined, welded, or brazed? Since many of the stainless steels are designed for specific fabricating advantages, a working knowledge of the available grades will greatly simplify selection.

Economics, of course, is a critical factor in the final choice. Cost and availability of material, cost of fabrication, expected life, installation and replacement costs all must be considered.

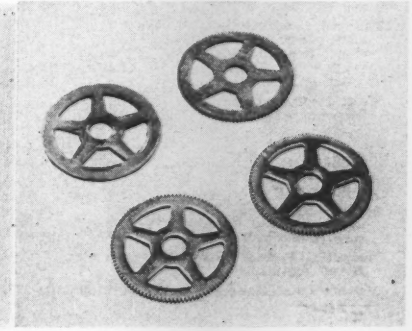
Group A — Martensitic (Hardenable) Stainless Steels: This group comprises the original stainless steels and forms the foundation of the entire family of stainless alloys. The name *martensitic* implies that all alloys of this group are hardenable by heat treatment. Basically, the group consists of steels containing 12 to 20 per cent chromium, together with controlled amounts of carbon. As the carbon is increased in an alloy of given chromium content, the range of mechanical properties which can be obtained by heat treatment is increased. However, as the carbon is increased, it ties up additional chromium in the form of the carbide, which in turn lowers the chromium available for corrosion resistance. Accordingly, with any appreciable increase in carbon, chromium must be increased to obtain comparable corrosion resistance. For example, in the hardened condition the corrosion resistance of a steel containing 0.30 per cent carbon and 12.0 per cent chromium is approximately equivalent to that of a steel containing 1.00 per cent carbon and 17.0 per cent chromium.

The martensitic steels offer excellent resistance to mild corrosives, the atmosphere, fresh water, steam, weak acids, oils, gasoline, soap, etc. However, they are not resistant to the more severe corrodents commonly encountered in chemical service.

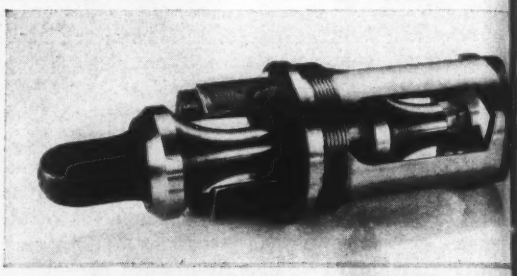
The analyses of the steels of this group are shown in TABLE 2, arranged according to AISI type numbers which provide a common identification throughout the industry. The physical properties of the martensitic steels are shown in TABLE 3.

The steels of Group A can be further classified into two divisions based on the mechanical properties which can be obtained by heat treatment. Types 403, 410, 414, 416, and 431 respond to heat treatment much like the SAE alloy steels containing 0.30 per cent carbon, such as SAE 2130, 3130, 4130, 6130. This response to heat treatment provides a broad range of mechanical properties, and affords the advantage of the corrosion resistance of the stainless steels in applications where extreme strength and toughness are

This gear wheel for a measuring instrument was previously a nonferrous metal, chrome plated. To obtain better wear properties, other metals were investigated. Extensive wear tests showed that stainless Type 416 (21-22 Rockwell C) gave required life. Gears are blanked and finish machined to tolerances on the pitch and outside diameters of 0.0004 and 0.0006-inch.



Originally a stainless casting, this 3-inch stream-flow type plunger and cage is part of a valve used to control flow of fluid under pressure. Wear resistance, strength and corrosion resistance are essential. Also, machining tolerances are close and finish is important. To cut costs, the design was changed from a casting to Type 416 bar stock. Besides meeting all basic requirements, the use of Type 416, heat treated to 300 Brinell, cut scrap losses 25 per cent, reduced material costs 50 per cent and increased production by 10 per cent.



required. For example, the following range of mechanical properties can be obtained by the controlled heat treatment of Type 410 which represents the base analysis of this class:

	Annealed	Hardened and Tempered
Yield Strength (0.2% offset, psi)	40,000	150,000
Tensile Strength (psi)	75,000	195,000
Elongation (% in 2 inches)	35	15
Reduction in Area (%)	70	55
Izod Impact (V-notch, ft-lb)	90	35
Hardness (Rockwell)	B-82	C-41
(Brinell)	155	390

Intermediate properties can be obtained by varying the tempering or drawing treatment, as shown in TABLE 4. These steels, Types 403, 410, 414, 416 and 431, can also be used in the annealed condition; they do not have to be hardened for maximum corrosion resistance. As suggested, they are used where their counterparts, the SAE alloy steels, are used but also where the additional property of corrosion resistance is important—mild springs, valve trim, pump rods, bolts, nuts, shafts, gears, and other machine parts.

Types 420 and 440-A, B, and C of this group are more nearly comparable to the tool steels. Their corrosion resistance is equivalent to the other stainless steels of Group A. However, due to their higher carbon content they must be fully hardened for maximum corrosion resistance; they should not be used in the annealed condition. Generally described as the cutlery steels, they can be hardened to 50-60 Rockwell C and are used in applications requiring extreme hardness and wear resistance. Typical uses include ball bearings, valve parts, plastic and rubber molds, knives, and cutting instruments of all kinds.

The steels of Group A, particularly the low-carbon analyses are also quite versatile for elevated temperature application. They resist oxidation up to 1200 F and are structurally dependable for highly stressed parts in service at temperatures up to 1000 F. Their strength and hardness at these temperatures are considerably higher than those of the carbon steels.

Fabrication of the martensitic steels, as with all stainless steels, can be accomplished without difficulty when the proper allowances are made for their greater strength. They can be forged, hot rolled, cold rolled, cold drawn, formed, bent, upset, coined, machined, and welded or brazed. However, it should be recognized that each grade has certain characteristics that expand or limit its response to a given fabricating technique. Successful fabrication requires an understanding of these characteristics.

Type 410, being the base analysis of the group, is balanced to contain just sufficient chromium and carbon for stainlessness and moderate mechanical strength. This steel can be read-

Table 3—Physical Properties of Group A Stainless Steels

(Martensitic)

	AISI Type Number				
	403, 410, 416	414	420	431	440 A,B,C
Modulus of Elasticity in Tension (psi×10⁻⁶)	29.0	29.0	29.0	29.0	29.0
Density (lb per cu in.)	0.28	0.28	0.28	0.28	0.28
Specific Heat (Btu per lb per deg F) 32-212 F	0.11	0.11	0.11	0.11	0.11
Thermal Conductivity (Btu per hr per sq ft per ft per deg F)					
212 F	14.4	14.4	14.4	11.7	14.0
932 F	16.6	16.6	...	...	...
Mean Coefficient of Thermal Expansion (per deg F × 10⁶)					
32-212 F	5.5	5.8	5.7	6.5	5.6
32-600 F	5.6	6.1	6.0	6.7	...
32-1000 F	6.4	6.7	6.5	...	...
32-1200 F	6.5	...	6.8	...	...
Specific Electrical Resistance at Room Temperature (ohms per cir mil ft)	343	421	331	438	361
Magnetic Permeability at H-200 (Annealed)	*	*	*	*	*
Melting Point Range (F)	2700-2790	2700-2790	2650-2750	2700-2790	2500-2700

* Magnetic.

ily hot worked— forged, headed, riveted, and upset. It is stiffer and stronger than mild steel at the temperature used for forging and consequently requires more blows or a heavier hammer. Because of the air hardening tendencies of the steel, large or intricate forgings should be cooled slowly from the forging temperature to prevent cracking. Small forgings can be air cooled.

In the annealed condition, Type 410 can be cold headed, blanked, formed or drawn. Its machinability is generally comparable to the SAE alloy steels containing 0.40 per cent carbon, although when dead-soft annealed, it is tough and draggy. It will machine better at higher hardness and can be machined at hardnesses up to 34 Rockwell C.

Type 410 can be satisfactorily welded by any of the arc or resistance welding techniques. In arc welding it should be preheated and welded with filler rods of similar analysis. If preheating is not possible, better results can be secured by using austenitic stainless (Group C) electrodes. Type 410 is usually annealed after welding to restore full ductility to the weld area.

Type 403 is designated as turbine quality. It is the prime grade of Type 410, melted and processed under rigid inspection standards. It is used almost exclusively for highly stressed rotating parts of turbines working at temperatures up to approximately 1100 F. The elevated temperature properties of Types 403 and 410 stainless steels are shown in TABLE 5.

Type 416 is a free-machining modification of the 410 analysis. The addition of small amounts of sulfur or selenium, as indicated in TABLE 2, markedly improves the machinability of the steel. It can be hot worked readily but is somewhat more tender than Type 410 in this respect. It is not recommended for severe cold forming applications, welding, brazing, or for vessels that must be pressuretight. It is used in all applications where Type 410 normally would be used but where ease of machinability is an important factor. It is well suited for use in automatic screw machines. Based on tonnage consumed, Type 416 is the most important steel of Group A.

Type 414 is developed by the addition of 2.00 per cent nickel to the Type 410 analysis. The nickel content serves a two-fold purpose. It contributes to improved mechanical properties (when heat treated) in the same manner as does an increase in carbon. However, unlike carbon, the nickel content also produces a slight increase in corrosion resistance. This steel is commonly produced in the form of tempered cold-rolled strip for the manufacture of springs, tempered rules, scraper knives and similar products requiring hardnesses in the range of 43-48 Rockwell C. This steel withstands a degree of forming unusual for this high hardness. In the annealed condition, Type 414 can be cold formed, blanked, and headed, although allowance must be made for its high annealed hardness.

Type 431 is designed to provide the maximum corrosion resistance consistent with the hardenable characteristics of the Group A steels. Its stainless quali-

Table 4—Average Mechanical Properties of Group A Stainless Steels

(Martensitic)

AISI Type No.	Hardening Temp. (F)	Tempering Temp. (F)	Yield Strength (0.2% offset, psi)	Ultimate Tensile Strength (psi)	Elongation (per cent in 2")	Reduction of Area (per cent)	Izod Impact (V-notch, ft-lb)	Hardness (Brinell)	Hardness (Rockwell)
403, 410	1800	300	150,000	195,000	15.0	55.0	35	390	C-41
		500	142,000	185,000	15.0	55.0	35	375	C-39
		700	146,000	190,000	16.0	55.0	30	390	C-41
		900†	130,000	168,000	18.0	60.0	..	341	C-36
		1000†	115,000	145,000	20.0	65.0	..	300	C-31
		1100	100,000	125,000	21.5	65.0	35	262	C-26
		1200	85,000	110,000	23.0	65.0	75	225	B-97
		Annealed	40,000	75,000	35.0	70.0	90	155	B-82
414	1800	300	155,000	210,000	15.0	55.0	45	444	C-46
		500	145,000	195,000	15.0	55.0	45	400	C-42
		700	150,000	200,000	16.0	58.0	..	415	C-44
		900†	134,000	170,000	18.0	60.0	..	352	C-37
		1000†	120,000	145,000	20.0	60.0	..	290	C-30
		1100	113,000	130,000	20.0	63.0	..	269	C-28
		1200	105,000	120,000	20.0	65.0	50	250	C-24
		Annealed	90,000	115,000	20.0	60.0	50	235	C-22
416	1800	300	150,000	195,000	10.0	40.0	20	390	C-41
		500	142,000	185,000	12.5	45.0	20	375	C-39
		700	146,000	190,000	13.0	48.0	26	390	C-41
		900†	130,000	168,000	14.0	50.0	..	341	C-36
		1000†	115,000	145,000	15.0	50.0	..	300	C-31
		1100	100,000	125,000	16.0	52.5	28	262	C-26
		1200	85,000	110,000	18.0	55.0	30	225	B-97
		Annealed	40,000	75,000	30.0	60.0	70	155	B-82
420	1900	400	215,000	250,000	8.0	25.0	10	512	C-52
		Annealed	50,000	90,000	28.5	59.0	..	196	B-93
431	1900	400	155,000	205,000	15.0	55.0	30	415	C-43
		Annealed	95,000	125,000	20.0	55.0	50	260	C-24
440A	1900	600	240,000	260,000	5.0	20.0	4	512	C-52
		Annealed	60,000	105,000	20.0	45.0	2	215	B-95
440B	1900	600	270,000	280,000	3.0	15.0	3	555	C-55
		Annealed	62,000	107,000	18.0	35.0	2	220	B-96
440C	1900	600	275,000	285,000	2.0	10.0	2	580	C-57
		Annealed	65,000	110,000	15.0	30.0	..	223	B-97

* For 1-inch diameter bars.
† Tempering at 750-1050 F results in rapid loss of hardness and impact values.

Table 5—Comparative Properties of Stainless Steels at Elevated Temperatures*

	Test Temp. (F)	AISI Type Numbers 403, 410	430	446	304	309	310	316	321	347
Short Time Tensile Strength (psi)	900	48,000	48,000	66,000	59,000	67,000	74,000	75,000	56,000	64,000
	1000	46,000	39,000	60,000	55,000	63,000	71,000	71,000	54,000	61,000
	1100	33,000	34,000	46,000	51,000	57,000	65,000	70,000	50,000	56,000
	1200	22,000	21,000	25,000	42,000	52,000	54,000	59,000	43,000	49,000
	1300	16,000	18,000	17,000	38,000	44,000	49,000	65,000	35,000	42,000
	1400	11,000	12,000	10,000	30,000	35,000	41,000	51,000	28,000	33,000
	1500	.....	8,500	8,000	24,000	28,000	34,000	40,000	22,000	25,000
Stress for Rupture in 1000 hours (psi)	900	34,000	30,000	.....	.....	.....	.....	.....	.....	.....
	1000	19,000	17,500	.....	.....	.....	32,000	.....	.....	.....
	1100	10,000	9,000	5,600	22,000	.....	22,000	33,000	26,000	31,000
	1200	.....	5,000	4,000	14,000	20,000	14,000	25,000	17,000	18,000
	1300	.....	.....	2,700	9,000	12,000	8,000	17,000	10,000	11,000
	1400	.....	.....	1,800	6,000	8,000	5,000	11,000	6,000	8,000
	1500	.....	.....	1,200	4,000	5,000	3,000	7,000	4,000	5,000
Stress for Creep Rate of 1% per 10,000 Hours (psi)	900	29,000	15,000	16,000	24,000	23,000	.....	.....	.....	.....
	1000	9,200	8,500	6,000	17,000	15,900	17,000	25,000	18,000	19,000
	1100	4,200	4,300	3,000	12,000	11,600	13,000	18,300	13,000	14,000
	1200	2,000	2,200	1,500	7,000	8,000	9,000	12,700	8,000	8,200
	1300	1,000	1,300	700	4,000	4,500	5,000	7,900	4,500	4,600
	1400	.....	800	300	2,500	2,500	2,300	4,500	2,400	2,500
	1500	.....	.....	.....	1,200	1,000	1,000	2,800	850	1,500
Safe Scaling Temperature for Continuous Service (F)	....	1200	1300	2000	1600	2000	2000	1600	1600	1600

* In the selection of an alloy for high-temperature service, it is necessary to consider not only scale resistance and strength but also the effect of temperature on hardness, toughness, structure, and corrosion resistance.

ties closely approach those of the 17 per cent chromium nonhardenable steel of Group B.

Although a relatively new steel in this country, Type 431 is being used in increasing quantities for high-strength structural members, fastenings and fittings which require somewhat greater corrosion resistance than is offered by the straight 12 per cent chromium steels of this group. The mechanical properties, heat treatment, and fabricating qualities of Type 431 are similar to those of Type 414.

Type 420 is the original stainless steel. The balance of carbon (normally about 0.30 per cent) and chromium produces the following mechanical properties when heat treated:

Yield Strength (0.2% offset, psi)	215,000
Tensile Strength (psi)	250,000
Elongation (% in 2 inches)	8
Reduction of Area (%)	25
Izod Impact (V-notch, ft-lb)	10
Hardness (Rockwell C)	52
(Brinell)	512

Fabrication of this steel requires attention. Forging or hot forming is readily accomplished, provided adequate precaution is taken to cool the part slowly from the forging heat to prevent cracking due to air hardening. Furnace cooling is preferred.

When annealed for maximum softness, Type 420 can be moderately cold formed, headed, or hobbed. It machines like a high-carbon tool steel. A modified analysis containing small amounts of sulfur or selenium, and designated as Type 420-F, is available where better machining properties are needed.

Type 420 is seldom welded because of its strong air-hardening tendencies. This steel is never used in the annealed condition because it requires hardening to bring out its corrosion resistance. Since it is more difficult to fabricate than the lower carbon Type 410, it should be used only in applications which demand the additional hardness and strength. Typical uses include gages, needle valves, ball check valves, gears, shafts, cams, pivots, ball bearings, valve parts, and cutting instruments. More recently, Type 420 has found wide use as a mold steel for plastics and rubbers. The free-machining grade, Type 420-F, is not suitable for this purpose.

The Type 440 steels offer the maximum hardness obtainable in the entire family of stainless steels. As indicated in TABLE 1, three grades are available containing varying amounts of carbon. As the carbon content is increased, the hardness obtainable by heat treatment increases, and the toughness and workability of the steel decrease. These steels must be fully hardened for corrosion resistance; accordingly, three carbon ranges are offered to provide the optimum combination of hardness, toughness and workability for all applications.

Generally, the 440 steels are somewhat more difficult to fabricate than Type 420; however, all opera-

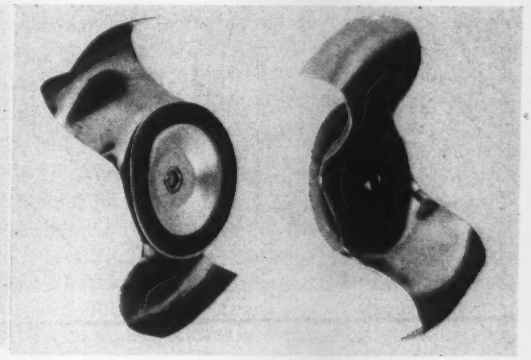
Table 6—Group B—Ferritic Stainless Steels

(Nonhardenable, Magnetic)

AISI Type No.	Carbon (per cent)	Chromium (per cent)	Other Elements (per cent)
405	0.07	12.50	Al 0.20
406	0.10	13.00	Al 3.50
430	0.10	17.00	.....
430F	0.10	17.00	S or Se 0.25
442	0.30	20.00	.....
443	0.15	20.00	Cu 1.00
446	0.30	27.00	N 0.15

Analyses are nominal; refer to TABLE 1 for composition limits.

This shock absorber must resist corrosion from condensation and tap water. It must have a spring temper and yet be formable. Previously this part was made from stainless Type 302, cold rolled to full hardness. Study showed it could be made successfully from heat-treated Type 410 strip. Critical alloys are saved, and the steel is lower in cost.



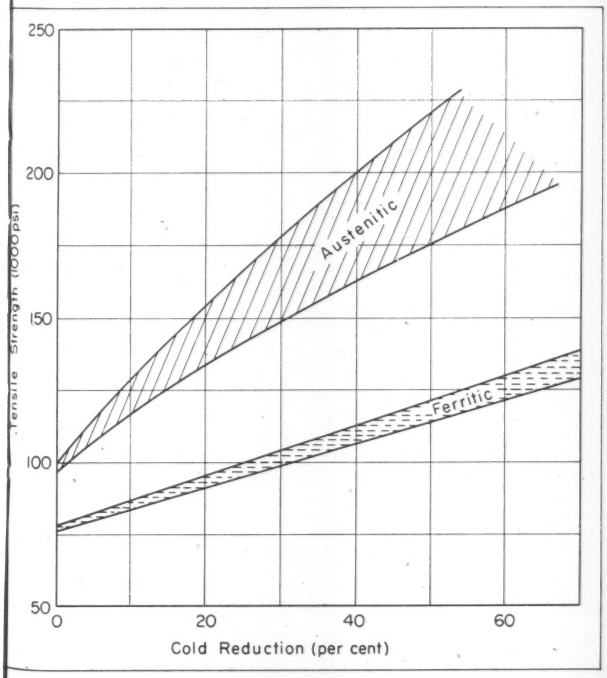
tions can be done on a commercial basis where the extra hardness and wear resistance are required. These steels can be forged, hot headed and upset, but as with Type 420, they must be cooled slowly from the forging heat to prevent cracking. They respond to simple cold-forming operations and when annealed for maximum softness can be headed and upset. The lower-carbon grades are easier to form.

These steels, because of their high carbon content, machine about the same as the high-speed tool steels. Free-machining analyses are available.

They are used in applications requiring maximum hardness and wear resistance: ball bearings, ball and seat valves, cutting instruments and miscellaneous machine parts.

Group B — Ferritic (Nonhardenable) Steels: The steels of this group, like those of Group A, are basically alloys of iron and chromium. However, in the ferritic steels, the element carbon is controlled to the lowest practical value in each steel to minimize its harmful effect on corrosion resistance and to provide a softer, more ductile metal. Further, the lowering of the carbon content produces steels which are not subject to appreciable hardening when cooled from high temperatures. This nonhardening tendency is of particular advantage in the fabrication of these steels by processes which involve heating, as for example, in hot working or welding.

Fig. 1—Work hardening properties of stainless steels

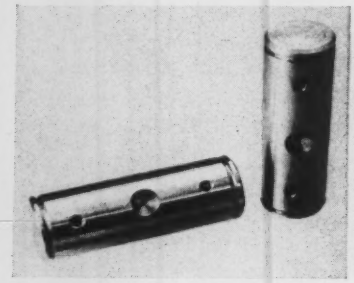


The ferritic group as shown in TABLE 6 includes alloys containing from 12 to 27 per cent chromium, each designed for a specific function. Generally, as the chromium content is increased, the corrosion resistance and oxidation or scaling resistance is increased. Several of the steels contain small percentages of other alloying elements; aluminum, to further suppress air hardening; sulfur or selenium, for improved machinability; copper, for increased corrosion resistance; and nitrogen to control grain size. These variations will be explained more fully under discussion of each type.

These steels are as a group more corrosion resistant than the hardenable grades, and accordingly are used in a greater variety of services. Briefly, there are three major fields of application:

1. In chemical processing industries, notably in the manufacture and handling of nitric acid and similar strongly oxidizing chemicals
2. In high-temperature installations requiring oxidation resistance. Use, however, in the high-temperature field is generally confined to assemblies where stresses are low as, for example, in resistance elements, soot blower tubes, and thermocouple protection tubes
3. In ornamental and functional designs which require resistance to rusting or staining; food handling equipment, hospital furniture, building hardware, and automotive trim are typical examples. Type 430, the base analysis of the group, is used extensively for applications of this type.

Physical properties of the steels of Group B are shown in TABLE 7. The ferritic steels do not respond to hardening by heat treatment; accordingly, the mechanical properties available, TABLE 8, are limited



This anchor pin acts as a pivot point for the brake shoe in a trailer axle brake. It requires a tough, corrosion-resistant steel. When specifications for the parts were changed from SAE 1137 to stainless Type 416, several advantages were obtained. Since the stainless was supplied precision ground, polished and heat treated, four to seven operations were eliminated in the manufacturer's plant. Moreover, plating to prevent rusting is no longer necessary and machining is easier.

when compared to the martensitic steels of Group A. Normally used in the annealed condition, these alloys offer greater strength and slightly better ductility than ordinary carbon steels. Mechanical properties of Type 430 are representative of the group and are shown below in comparison to the familiar SAE 1010. Tests were conducted with 1-inch diameter bars.

	Type 430	SAE 1010
Yield Strength (0.2% offset, psi)	45,000	26,000
Tensile Strength (psi)	75,000	47,000
Elongation (% in 2 inches)	30	28
Reduction of Area (%)	65	50
Hardness (Rockwell B)	82	56
(Brinell)	155	95

Strength of these steels can be moderately increased by cold working. The relative work-hardening properties of the ferritic steels as a group are shown in *Fig.* 1. Tensile strengths up to 125,000 psi are obtainable in strip, wire, and similar sections which can be drastically cold worked.

The ductility and relative softness of the ferritic grades permits fabrication by practically all of the standard techniques. Hot working and forging operations are somewhat simpler than for the martensitic steels since the danger of cracking due to air hardening is eliminated. Similarly, these steels can be welded with greater ease; however, the higher chromium steels of the group are susceptible to grain coarsening and embrittlement in the heat-affected zone of the weld and consequently they are normally annealed after welding to restore ductility. In heavy weld sections requiring the use of filler rods, it is common practice to use austenitic (Group C) electrodes to provide a tougher, more ductile weld bead. The ferritic steels are readily cold formed by rolling, spinning, roll forming, bending, drawing, etc. They have a low rate of work hardening and a relatively high yield strength. This combination of properties encourages localized thinning or necking down under tensile stresses which requires that caution be exercised in cold forming operations that involve stretching, such as deep drawing. The machinability of these steels is generally comparable to that of Type 410.

The various grades included in the ferritic group are as follows:

Type 405 is essentially a modified Type 410 stainless. The carbon content is kept as low as is commercially possible, and a small amount of aluminum is added to completely suppress the hardening properties of the steel. It is designed for applications which involve welding but which cannot be annealed to re-

Table 7—Physical Properties of Group B Stainless Steels
(Ferritic)

	AISI Type Number					
	405	406	430	442	443	446
Modulus of Elasticity In Tension (psi × 10^{-6})	29.0	29.0	29.0	29.0	29.0	29.0
Density (lb per cu in.)	0.28	0.265	0.28	0.28	0.28	0.27
Specific Heat (btu per lb. per deg F) 32-212 F	0.11	0.11	0.11	0.11	0.11	0.12
Thermal Conductivity (btu per hr per sq ft per foot per deg F)						
212 F	...	...	15.1	12.5	12.5	12.1
932 F	...	...	15.2	14.2	...	14.1
Mean Coefficient of Thermal Expansion (per deg F × 10^{6})						
32-212 F	6.0	6.3	5.8	5.8	5.3	5.8
32-600 F	6.4	6.6	6.1	6.1	6.1	6.0
32-1000 F	6.7	6.8	6.3	6.3	6.4	6.2
32-1200 F	...	...	6.6	6.6	6.7	6.4
32-1500 F	7.5	7.9	...	...	...	...
Specific Electrical Resistance at Room Temperature (ohms per cir mil ft)	361	720	361	384	409	403
Magnetic Permeability at H-200 (Annealed)	*	*	*	*	*	*
Melting Point Range (F)	2700–2790	.....	2600–2750	2600–2750	2600–2750	2600–2750

* Magnetic.

store ductility. The major use for this grade is in welded linings for refinery equipment where strength and corrosion resistance are required in the temperature range 700 to 1000 F. A considerable tonnage is also used for steam turbine stator blades which after forging or machining to shape are integrally cast with the turbine wheel.

In Type 406 the high percentage of aluminum performs several functions. In addition to suppressing hardenability, it contributes greatly improved oxidation resistance and sharply increases the electrical resistivity of the metal. Type 406 is used almost exclusively as a low-cost electrical resistance element for service at temperatures up to 1600 F.

Type 430 stainless steel is the most important and most versatile steel of the group. Although one of the first types of stainless steels commercially manufactured, it has only recently come into prominent use. In 1943 it accounted for 3 per cent of all stainless produced. This figure had increased to 30 per cent in 1950, and is even higher today because of the limited availability of the chromium-nickel stainless steels. This gain in popularity is due in part to the development of improved fabricating techniques.

The corrosion resistance of Type 430 is exceptionally good, approaching that of the chromium-nickel steels of Group C. It resists corrosion by the atmosphere, fresh water, foodstuffs, dairy products, nitric acid, and a great variety of organic and inorganic chemicals. It does not, however, have the added resistance to pitting typical of the Group C steels. This is a factor to be considered in applications involving corrosive chemicals.

Type 430 is well adapted to the various fabricating procedures. Forging of this steel presents no problems. Although stronger and stiffer than mild steel at forging temperature, it is extremely malleable, and can be forged to the most complex shapes. It can be hot worked over a relatively broad temperature range; however, precautions must be taken to avoid overheating and grain coarsening. Forged parts can be air cooled without danger of cracking.

The 430 analysis is particularly suited for cold-forming operations, such as spinning, roll forming, blanking, stamping, etc. Practically all of the intricate moldings used in automotive trim are cold-formed Type 430 strip steel. Deep-drawn parts can also be made successfully. Its drawing characteristics are somewhat like those of mild steel. Drawing should be accomplished in gradual stages, and emphasis placed on die design to avoid stretching of the metal. In this respect, the steel does have some limitations when compared to the tougher, more ductile austenitic steels of Group C. With proper consideration of these differences, equally satisfactory results can be obtained.

Weldability is good although welded structures should be annealed to restore full corrosion resistance and ductility. Recent developments have produced a modified analysis containing titanium which has simplified this problem.

Uses of this steel are almost too numerous to mention. By far the greatest tonnage goes into decorative or ornamental applications, but it is also widely used in the chemical industry and in industrial heating installations for resistance to oxidation at temperatures up to 1500 F.

Type 430-F is the free-machining counterpart of the foregoing type. Its ductility and formability are not quite as good as the standard Type 430 and it is generally reserved for parts which require extensive machining. As with all free-machining stainless steels, it is not recommended for fabrication by welding.

Type 442 is generally classed as a heat-resistant steel and is widely used for scale-resisting purposes.

Type 443 containing approximately 1 per cent copper offers several advantages over the companion alloy, Type 442. The copper content provides additional corrosion resistance in certain chemicals, particularly in dilute sulfuric acid where its resistance is even better than the 18 per cent chromium, 8 per cent nickel steels of Group C. Type 443 is also resistant to mixed acid solutions as used in nitration processes. It has excellent oxidation resistance and is used extensively for furnace parts, stationary soot blower elements, stirring rods and ladles for molten, nonferrous metals. The fabricating qualities are similar to those of the 430 analysis; however, some allowances must be made for the lower ductility of this steel.

Type 446 is a corrosion and heat-resisting steel

Table 8—Average Mechanical Properties* of Group B Stainless Steels

(Ferritic)

AISI Type No.	Heat Treatment	Yield Strength (0.2% offset, psi)	Ultimate Tensile Strength (psi)	Elongation (per cent in 2")	Reduction of Area (per cent)	Izod Impact (V-notch, ft-lbs)	Hardness (Brinell)	Hardness (Rockwell B)
405	Annealed	40,000	70,000	30.0	60.0	†	150	81
406	Annealed	50,000	86,000	25.0	57.0	†	187	90
430	Annealed*	45,000	75,000	30.0	65.0	†	155	82
430 F	Annealed	55,000	80,000	15.0	55.0	†	170	86
442	Annealed	50,000	80,000	20.0	40.0	†	170	86
443	Annealed	50,000	90,000	22.0	55.0	†	187	90
446	Annealed	50,000	80,000	25.0	45.0	†	170	86

* For 1-inch diameter bars.

† These steels have excellent bend toughness but may show low notch toughness depending on composition and heat treatment.

Table 9—Physical Properties of Group C Stainless Steels

(Austenitic)

	AISI Type Number							
	301	302, 303 304, 308	305	309	310	314	316, 317	321, 347
Modulus of Elasticity in Torsion (psi × 10^{-6})	28.0	28.0	28.0	29.0	29.0	29.0	28.0	28.0
Modulus of Elasticity in Torsion (psi × 10^{-6})	12.5	12.5	12.5	...	...	...	...	...
Density (lb per cu in.)	0.29	0.29	0.29	0.29	0.29	0.279	0.29	0.29
Specific Heat (btu per lb per deg F) 32-212 F	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Thermal Conductivity (btu per hr per sq ft per ft per deg F)								
212 F	9.4	9.4	9.4	8.0	8.0	10.1	9.4	9.3
932 F	12.4	12.4	12.4	10.8	10.8	12.1	12.4	12.8
Mean Coefficient of Thermal Expansion (per deg F × 10^{6})								
32-212 F	9.4	9.6	9.2	8.3	8.0	...	8.9	9.3
32-600 F	9.5	9.9	9.9	9.3	9.0	8.4	9.0	9.5
32-1000 F	10.1	10.2	10.3	9.6	9.4	...	9.7	10.3
32-1200 F	10.4	10.4	10.5	10.0	9.7	...	10.3	10.6
32-1500 F	...	...	...	...	...	9.8	11.1	11.2
Specific Electrical Resistance at Room Temperature (ohms per cir mil ft)	433	433	445	469	469	468	445	438
Magnetic Permeability at H-200 (Annealed)	1.02	1.02	1.003	1.02	1.003	1.01	1.02	1.02
Melting Point Range (F)	2550-2590	2550-2590	2550-2600	2550-2650	2550-2650	...	2500-2550	2550-2600

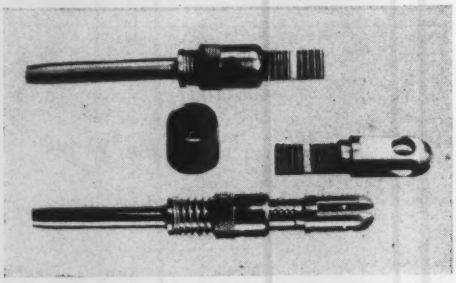
with the maximum amount of chromium consistent with commercial malleability. The nitrogen content shown in TABLE 2 is intentionally added to inhibit grain coarsening and embrittlement at elevated temperatures.

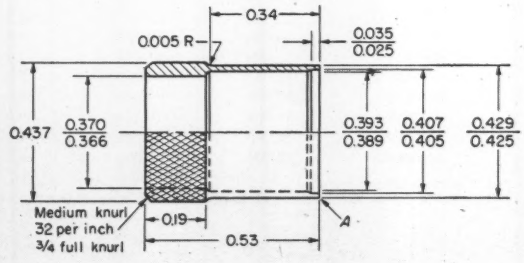
This alloy is principally used for its excellent oxidation resistance at temperatures up to 2000 F. As with all of the ferritic steels, it has little high-temperature strength and is used in applications where stresses are low and support is good. Typical applications include all types of furnace parts, baffles, rabble arms, kiln linings, etc.

Corrosion resistance of Type 446 surpasses that of the lower chromium steels of the B Group. It is particularly useful in processes which include alternating exposure to oxidizing and reducing chemicals as in the manufacture of synthetic rubber by catalytic dehydrogenation. The low ductility associated with the chromium content of this steel introduces fabricating difficulties, particularly in cold forming or welding operations.

Group C — Austenitic (Nonhardenable) Stainless Steels: The austenitic or chromium-nickel stainless steels comprise a group of iron alloys containing from 16 to 26 per cent chromium and from 6 to 22 per cent

Assembly nut for this aircraft fitting was originally a copper-nickel alloy. The problem was to reduce costs and find a corrosion-resistant alloy that offered better, uniform machinability. Stainless Type 416 was selected. Production on automatic screw machines was increased, costs were cut and rejects eliminated on the difficult machining of the thin wall and spinning of the edge to form the thin lip at point *A*.





nickel. These steels are noted for high strength accompanied by exceptional toughness, ductility, and formability. As a class, the austenitic grades exhibit considerably better corrosion-resisting qualities than the martensitic or ferritic steels. Further, they have excellent strength and oxidation resistance at elevated temperatures.

Although classed under the general heading of stainless steels, the austenitic steels form a family of metals quite different from the straight iron-chromium alloys of Group A and Group B. The addition of large amounts of nickel changes the fundamental crystal structure and with it the entire nature of the metal. As indicated in TABLE 9, even the physical constants are altered, thermal conductivity is lowered, the coefficient of expansion is almost doubled, electrical resistivity increases, and the metal becomes nonmagnetic.

The nominal type analyses of the steels of this group are shown in TABLE 10. It will be noted that the majority of these alloys are modifications of the basic 18 per cent chromium, 8 per cent nickel analysis. Although the analysis variations appear slight, these variations produce significant changes in the properties and corrosion resistance of the steels. As in the ferritic steels, the element carbon is present as an impurity, and is held to the commercial minimum.

The relative proportion of chromium and nickel exerts a strong influence on the mechanical properties and workability of the steels and is controlled in Types 301, 302, 304, and 305 to produce a distinct series of alloys. In general, steels with a high chromium to nickel ratio (for example, Type 301) will harden rapidly when cold worked and are suited for high-strength applications. Conversely, those with a low chromium to nickel ratio (for example, Type 305) are more workable and are designed for fabricating advantages.

Minor alloying elements also contribute important effects. Molybdenum enhances the passivating qualities of the metal and markedly improves its resistance to pitting corrosion. The titanium or columbium additions in Types 321 and 347 aid in controlling the carbon by combining with it to form relatively harmless carbides—thus reducing the tendency toward intergranular corrosion. These elements also produce an appreciable increase in the strength of the metal at elevated temperatures.

The chromium-nickel stainless steels as a group exhibit a higher level of corrosion resistance than is shown by the straight-chromium steels. The difference is principally one of degree; however, there is a wide variety of chemicals which can be handled only by the austenitic stainless steels. The 18-8 steels of the group, Types 301, 302, 303, 304, 305, 321 and 347, show the same general order of corrosion resistance. There is some gain with increased alloy content but the selection of these steels normally depends on mechanical requirements or fabricating techniques.

Types 309 and 310, commonly classed as heat-resistant alloys, are also useful in chemical service. They resist the same corrodents as the 18-8 types but will withstand higher concentrations and temperatures. Type 316 containing molybdenum is the most corrosion resistant of all of the standard stainless steels. Its outstanding value is its improved resistance to pitting in corrosive environments which tend to destroy the passivity of the stainless steels. This class of corrosives includes dilute sulfuric or sulfurous acids, phosphoric acid, acetic acid, weak neutral chloride solutions and a variety of reducing organic acids. It is well to note that the stainless steels, including Type 316, are not recommended for use in hydrochloric acid, chloride salt solutions, nor in the salts or acids of the related elements, fluorine, bromine and iodine.

The excellent corrosion resistance of the austenitic

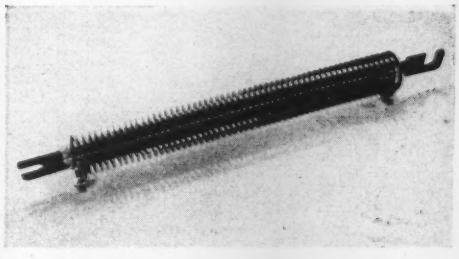
Table 10—Group C Austenitic Stainless Steels

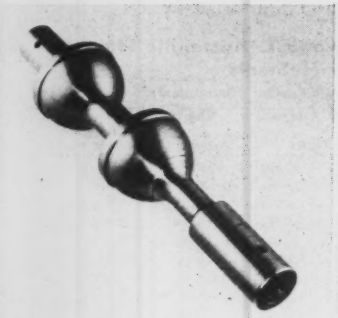
(Nonhardenable, Nonmagnetic)

AISI Type No.	Carbon (per cent)	Chromium (per cent)	Nickel (per cent)	Other Elements (per cent)
301	0.12	17.00	7.00	....
302	0.12	18.00	9.00	....
302B	0.12	18.00	9.00	Si 2.50
303	0.12	18.00	9.00	S or se 0.25
304	0.07	19.00	10.00	....
305	0.12	18.00	12.00	....
308	0.07	20.00	11.00	....
309	0.15	23.00	13.00	....
310	0.20	25.00	20.00	....
314	0.20	25.00	20.00	Si 2.50
316	0.08	18.00	12.00	Mo 2.50
317	0.08	19.00	12.50	Mo 3.50
321	0.07	18.00	10.00	Ti 0.40
347	0.07	18.00	11.00	Cb 0.70

Analyses are nominal; Refer to Table 1 for composition limits.

To reduce the cost of this electrical resistor without impairing its performance, stainless Type 406 was successfully adopted. No retooling was necessary in fabrication, and the stainless was considerably lower in cost than the special resistance alloys used previously.





When parts must have corrosion resistance plus high hardness, a stainless grade such as 440-C should be considered. Straight-chromium 440-C, which is used for the 8 3/16-inch long inner valve plug shown here, can be treated to 58-60 Rockwell C. In this condition, it withstands corrosion and erosion encountered in the handling of liquid under high pressure.

steels accounts for their use in a great many applications but of equal importance is their outstanding combination of mechanical properties. Normally used in the annealed condition, these steels as shown in TABLE 11 have a high tensile strength coupled with high toughness, ductility, and formability. The properties of Type 302 are representative of the group and are shown below:

Yield Strength (0.2% offset, psi)	35,000
Tensile Strength (psi)	85,000
Elongation (% in 2 inches)	60
Reduction of Area (%)	70
Izod Impact (V-notch, ft-lb)	110
Hardness (Rockwell B)	81
(Brinell)	150

Chromium-nickel steels, like the ferritic steels of Group B, cannot be hardened by heat treatment. They do, however, work harden rapidly when cold worked and can be appreciably strengthened in this manner. This response to cold working is a function both of analysis, as previously discussed, and of degree of cold deformation. The general influence of cold reduction is shown in *Fig.* 1. As might be anticipated, parts with large cross-sections cannot be strengthened in this way, whereas extremely fine wire or strip which can be drastically cold drawn or rolled can be processed to tensile strengths as high as 325,000 psi.

The increase in strength and hardness by cold working is, of course, accompanied by a reduction in ductility. However, even the most drastically cold-worked material retains sufficient ductility for many fabricating operations.

Austenitic steels also possess a desirable combination of mechanical properties at subzero temperatures. These alloys, unlike the martensitic and ferritic steels, retain most of their toughness and ductility at temperatures approaching absolute zero. For example, tensile properties of annealed Type 304 at room temperature and at −320 F are as follows:

	70 F	−320 F
Yield Strength (0.2% offset, psi)	35,000	39,000
Tensile Strength (psi)	85,000	246,000
Elongation (% in 2 inches)	60	32
Reduction of Area (%)	70	55
Izod Impact (V-notch, ft-lb)	110	110

The excellent mechanical properties of the chromium-nickel steels greatly facilitate fabrication. These steels can be hot worked without difficulty and like the ferritic steels can be air cooled from forging temperature without danger of cracking. However, when heated in, or cooled slowly through the temperature range of 800 to 1650 F, the carbon in the steel precipitates in the grain boundaries as chromi-

Table 11—Average Mechanical Properties* of Group C Stainless Steels

(Austenitic)

AISI Type No.	Heat Treatment	Yield Strength (0.2% offset, psi)	Ultimate Tensile Strength (psi)	Elongation (per cent in 2")	Reduction of Area (per cent)	Izod Impact (V-notch, ft-lbs)	Hardness (Brinell)	Hardness (Rockwell B)
301	Annealed	40,000	105,000	55.0	70.0	110	165	86
302	Annealed	35,000	85,000	60.0	70.0	110	150	81
302 B	Annealed	40,000	90,000	50.0	65.0	90	160	84
303	Annealed	35,000	90,000	50.0	55.0	80	160	84
304	Annealed	35,000	85,000	60.0	70.0	110	150	81
305	Annealed	36,000	82,000	56.0	73.0	110	156	83
308	Annealed	30,000	85,000	55.0	65.0	110	150	80
309	Annealed	40,000	95,000	45.0	65.0	110	160	84
310	Annealed	45,000	95,000	50.0	65.0	90	185	89
314	Annealed	50,000	100,000	45.0	60.0	80	180	90
316	Annealed	30,000	85,000	60.0	70.0	110	150	81
317	Annealed	40,000	85,000	50.0	60.0	110	160	84
321	Annealed	35,000	85,000	55.0	65.0	110	150	80
347	Annealed	35,000	90,000	50.0	65.0	110	160	84

* For 1-inch diameter bars.

um carbide. This condition renders the steel susceptible to intergranular corrosion. Accordingly, parts which have been air cooled must be annealed by reheating to approximately 2000 F, followed by water quenching to restore full corrosion resistance. This same condition is encountered when welding these steels. Strong, tough welds are easily obtained, using standard equipment and techniques, but the weld area is unavoidably heated to this critical range and must be subsequently annealed. The problem of intergranular carbide precipitation can be avoided by using Types 321 or 347. The carbon in these steels is "stabilized" by combining it with the carbide forming elements, titanium or columbium.

Austenitic stainless steels are particularly suited for cold forming operations, using the recommended techniques. They can be deep drawn, spun, roll formed, blanked, perforated and cold headed without difficulty. The cold work-hardening properties of these steels places some limit on the amount of cold forming which can be done. However, by selecting the steel with the proper rate of work-hardening, many of the most severe deep drawing and forming jobs can be accomplished without an intermediate annealing treatment.

Machining of the austenitic steels generally requires slower speeds than those used with the straight-chromium steels. Satisfactory results are obtained with the proper tool design and lubrication. Type 303, the free-machining grade, is recommended for parts which involve extensive machining.

A brief description of each grade is presented to aid in the proper selection of these steels.

Type 301 work hardens rapidly when cold worked and is designed for high-strength applications. It is produced commercially in various tempers with the following range of mechanical properties:

	Annealed	Full-Hard
Yield Strength (psi)	40,000	140,000 min
Tensile Strength (psi)	110,000	185,000 min
Elongation (% in 2 inches)	60	9 min

Because of its relatively low alloy content, its corrosion resistance is not quite comparable to Type 302. Type 301 is normally produced in the form of cold-rolled strip or sheet for structural components of aircraft, railroad cars, and truck bodies.

Type 302 is a general-purpose 18-8 alloy. It does not work harden as rapidly as Type 301 and responds readily to drawing, forming, bending and upsetting operations. However, it can be materially strengthened by cold working and is frequently produced in cold-rolled strip and cold-drawn wire for the manufacture of springs, stampings, moldings, woven screens, cables, etc.

The ease with which Type 302 can be fabricated has encouraged its use in many applications where the straight chromium steels such as Type 430 would normally be used. With the present shortage of nickel, the designer will do well to study these applications carefully with the technical assistance of materials engineers to determine whether or not the less-expensive straight-chromium Type 430 can be substituted for one of the more costly austenitic stainless steels.

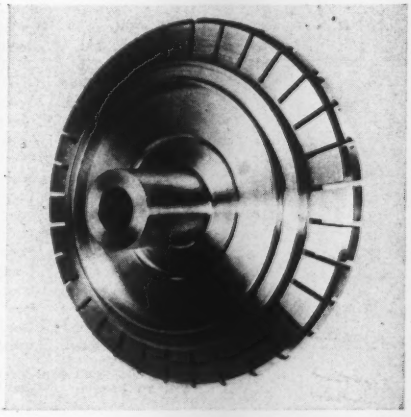
Type 302, characteristic of the austenitic steels, is essentially immune to all foodstuffs, sterilizing solutions, most of the organic chemicals and dyestuffs, and a wide variety of inorganic chemicals. It is the most widely used steel of the group. The high silicon modification, Type 302B provides improved oxidation resistance at elevated temperatures.

Type 303, generally manufactured in bar form, is used for all parts that are fabricated by machining, grinding and polishing. It is suited for screw machine products, valves, valve trim, shafting and machinery parts of all types. It is not recommended for welding nor for pressuretight fittings.

Type 304 is a low-carbon modification of Type 302. It is a better material for welding and in thin sections can be welded with less trouble from intergranular corrosion. The corrosion resistance and formability of this analysis is somewhat superior to that of Type 302 and it is widely used in the chemical and food processing industries.

Type 305, the deep-drawing stainless steel, has a balanced analysis designed for maximum formability. Excellent ductility, coupled with an extremely low rate of work hardening, renders this steel suitable

This disk holds cutting knives in a candy-wrapping machine. Requirements called for a steel with high strength and enough corrosion resistance to withstand the attack of sugar and fruit acids. At the same time, good machinability is important because the knife slots must accommodate the knives without play. Originally 18-8 stainless was specified but it was found that a chromium-nickel steel provided more corrosion resistance than was necessary. It was also more costly. Stainless Type 416 provided the necessary strength and corrosion resistance—along with better machinability. Tolerances of plus 0.002-inch and minus 0.000 were maintained.



for the most severe deep-drawing and spinning operations.

Type 308, containing higher chromium and nickel than the typical 18-8 analyses, is most commonly produced in wire form for the manufacture of general-purpose welding electrodes. It is used for the welding of the nonstabilized stainless steels, Types 301, 302, 304 and 305. Type 308 welding rod is also used in the welding of the martensitic and ferritic grades, and in the repair welding of mild steel and cast iron where tough ductile welds are required.

Types 309 and 310 are generally classed as heat resisting steels and are widely used for furnace parts, annealing boxes, soot blowers, heat exchanger tubing and similar parts where strength and oxidation resistance are required. These steels are stronger than the ferritic steels and are equally resistant to scaling at temperatures up to 2000 F. The high-temperature properties of the various grades are shown in TABLE 5 and compared graphically in *Figs.* 2 and 3.

Type 310, the richer of the two steels, offers superior resistance to gaseous corrodents, including sulfur compounds at high temperatures, and is used in considerable quantities in refinery equipment. Type 310 is also used for structural parts of internal combustion and jet engines which are exposed to hot corrosive exhaust gases. Both grades can be forged, hot formed, cold formed and welded without difficulty; however, they do require closer control of fabricating procedures because of their higher alloy content. Available in the lower carbon analyses, designated as 309S and 310S (TABLE 1), these grades are useful in chemical service. They resist the same general types of corrodents as Type 304 but provide a greater margin of safety and can be used at higher concentrations and temperatures.

Type 314, a high-silicon variation of Type 310, is particularly resistant to carburizing atmospheres commonly encountered in heat-treating equipment.

Type 316 is considered the most corrosion resistant of all of the standard stainless steels, extending the usefulness of these steels to a broader field. Originally designed for resistance to sulfite solutions encountered in the paper pulp industry, this steel has been found exceptionally resistant to pitting corrosion. It is used in many applications where the straight-chromium-nickel steels have shown borderline resistance. These include dilute sulfuric acid, sulfurous acid, phosphoric and acetic acids, and severe marine and industrial atmospheres.

Type 317 is a modification of Type 316, containing higher molybdenum. This steel has been used in several special applications where the resistance of Type 316 was found inadequate. The manufacture of Type 317 has been curtailed the present.

Types 321 and 347, the stabilized stainless steels, are so called because they contain elements which combine with carbon to form stable titanium or columbium carbides. As previously discussed, this is an important function, for it prevents the harmful formation of chromium carbides during welding or when exposed in the temperature range of 800 to 1650 F. Unlike the straight-chromium-nickel types, their corrosion resistance is not impaired by welding.

Both these steels are recommended for parts which are to be used in the as-welded condition, and for equipment operating at temperatures up to 1700 F. At elevated temperatures, these grades are appreciably stronger than the other steels of the group, with the exception of Type 316. Typical uses include chemical process equipment for both room and elevated temperatures, expansion parts, and aircraft collector rings and exhaust manifolds.

Of the two, Type 347 offers several advantages; its corrosion resistance, equal to that of Type 304, is somewhat better than that of Type 321, particu-

Table 12—Relative Workability of Stainless Steel

AISI Type No.	Blanking Punching & Perforating	Buffing	Deep Drawing and Stamping	Hot Forging	Cold Forging	Cold Forming	Hot Heading	Cold Heading	Machinability (Turning fpm)	Magnetic?	Hot Riveting Above ¼" Dia.	Cold Riveting Up to ¼" Dia.
302	Good	Excellent	Good	Good	Good	Good	Good	Good	40-85	No	Good	Good
304	Good	Excellent	Good	Good	Good	Good	Good	Good	40-85	No	Good	Good
303	Good	Excellent	Poor	Good	Poor	No	Good	Good	85-120	No	Good	Good
305	Good	Excellent	Good	Good	Good	Good	Good	Good	40-85	No	Good	Good
316	Fair	Good	Good	Good	Fair	Good	Fair	Fair	40-85	No	Fair	Fair
317	Fair	Good	Good	Good	Fair	Good	Fair	Fair	40-85	No	Fair	Fair
321	Good	Excellent	Good	Good	Good	Good	Good	Good	60-90	No	Good	Good
347	Good	Excellent	Good	Good	Good	Good	Good	Good	60-90	No	Good	Good
No. 10	Good	Excellent	Good	Good	Excellent	Good	Good	Excellent	40-85	No	Good	Excellent
No. 20	Good	Excellent	Good	Good	Good	Good	Good	Good	50-90	No	Good	Good
403	Good	Excellent	Good	Good	Good	Good	Good	Good	80-115	Yes	Good§	Good
410	Good	Excellent	Good	Good	Good	Good	Good	Good	80-115	Yes	Good§	Good
414	Good	Excellent	Poor	Good	Poor	No	Slight	Poor	40-80	Yes	Poor	Poor
416	Good	Excellent	Poor	Good	Poor	No	Good	Slight	110-140	Yes	Good§	Slight
420	Good	Good	Poor	Good	Slight	Fair†	Good	Good†	40-80	Yes	Slight†	Slight
420F	Good	Good	Poor	Good	Poor	No	Fair	Fair†	80-110	Yes	Slight†	No
430	Good	Excellent	Good	Good	Good	Good	Good	Good	85-115	Yes	Good§	Good
430F	Good	Excellent	Poor	Good	Poor	No	Good	Slight	120-150	Yes	Good§	Poor
440A	Fair	Good	Poor	Good	Slight	Fair	Fair	Fair	40-80	Yes	Slight	No
440C	Fair	Good	Poor	Fair	Poor	Fair	Fair	Fair	40-60	Yes	Slight	No
443	Good	Excellent	Good	Good	Good	Good	Good	Good	80-110	Yes	Good§	Good

1. Use Types 304, 308, 316 coated rods. Avoid atomic hydrogen. 2. Satisfactory. Will air harden. 3. Weld brittle below 200 F 5. Fair. Will air harden. * Requires high pressure. § Below 1400 F. † If specially annealed. ‡ Tool life poor.

larly in strongly oxidizing solutions such as hot concentrated nitric acid. Further, in welding, the columbium is retained in the weld metal, whereas with Type 321 some of the titanium is lost due to oxidation. Accordingly, Type 347 welding electrodes are required for the welding of Type 321. For these reasons, Type 347 has been used almost to the exclusion of Type 321 in this country. Unfortunately, because of the acute shortage of columbium, the 347 analysis has been withdrawn from the commercial market, although with proper CMP ratings, it can be obtained in the form of welding rod for the manufacture of equipment which *cannot* be annealed after welding.

In addition to the standard grades which have been described, there are a number of nonstandard and some proprietary steels which deserve attention.

One of the most significant developments in the field of corrosion-resistant alloys is the production of a sulfuric-acid-resistant stainless steel in rolled forms. This steel, identified by the trade name Carpenter Stainless No. 20, was previously available only in the form of castings under the familiar trade name, Durimet 20.* It is an austenitic steel containing 20 per cent chromium, 29 per cent nickel, 2 per cent molybdenum and 3 per cent copper. However, despite its high alloy content, it is of considerable importance in the conservation program. Its outstanding resistance to corrosion permits its use in equipment formerly made of nickel-base alloys containing appreciably higher percentages of critical elements. Stainless No. 20 is widely used in all phases of the chemical, rubber and refinery industries.

Also significant in the field of stainless steels for use in chemical service is the introduction of the very low-carbon austenitic steels. Advanced melting techniques have made it possible to produce these steels

* Duriron Co. Inc.

Cold Shearing	Soldering	Swaging	Fusion and Resistance Welding	AISI Type No.
Good	Good	Good	Good	302
Good	Good	Good	Good	304
Good	Poor	Slight	Note 1	303
Good	Good	Good	Good	305
Good	Fair	Fair	Good	316
Good	Fair	Fair	Good	317
Good	Good	Good	Good	321
Good	Good	Good	Good	347
Good	Good	Good	Good	No. 10
Good	Good	Good	Excellent	No. 20
Good	Good	Good	Note 2	403
Good	Good	Good	Note 2	410
Good	Fair	No	Note 2	414
Good	Poor	Slight	Note 1	416
Fair	Fair	Fair	Note 2	420
Fair	Poor	Slight	Note 1	420F
Good	Good	Good	Note 3	430
Good	Poor	Slight	Note 1	430F
Fair	Fair	Slight	Note 4	440A
Fair	Fair	Slight	Note 5	440C
Good	Good	Good	Excellent	443

200 F. 4. Fair if slow cooled from welding temperature.

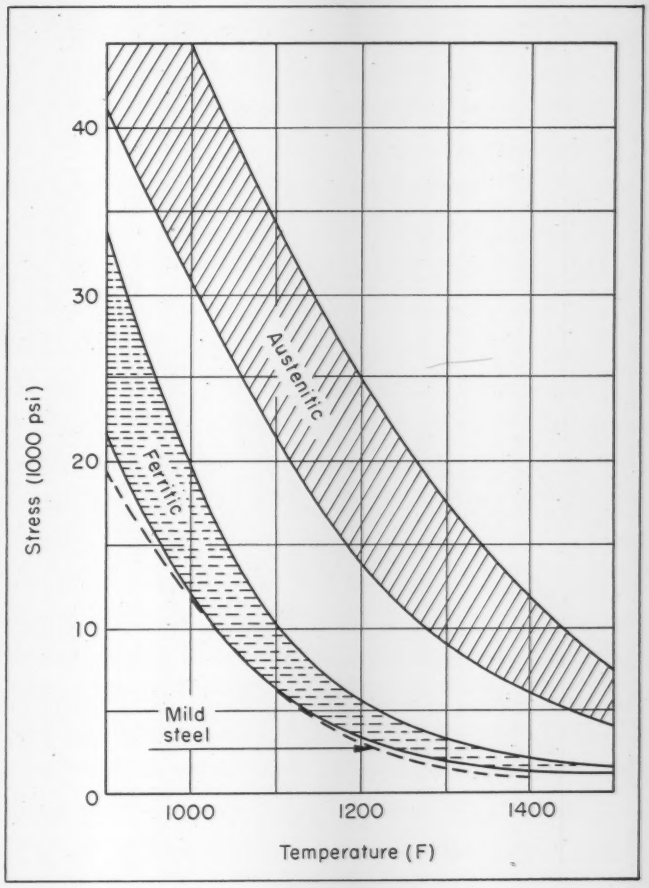
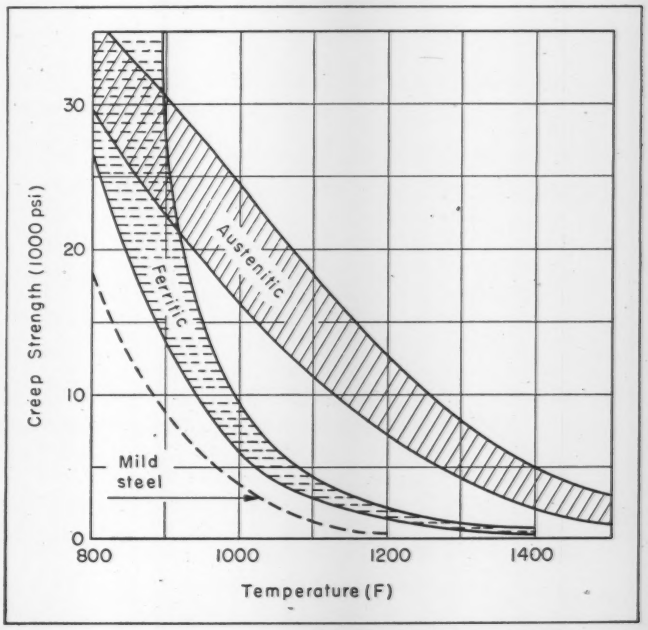


Fig. 2—Above—Stress required for rupture in 1000 hours versus temperature

Fig. 3—Below—Stress for one per cent creep rate per 10,000 hours versus temperature



containing less than 0.03 per cent carbon. This lowering of the carbon, like the addition of the stabilizing elements titanium and columbium, minimizes the harmful precipitation of chromium carbide during welding and eliminates the need for annealing after welding. Generally available in two grades, Types 304L and 316L, these 0.03 per cent maximum carbon steels have replaced Types 321 and 347 for welded construction in service at temperatures below 800 F. These steels are not recommended for service at elevated temperatures.

Type 329 stainless steel, one of the lesser known stainless steels, is rapidly growing in importance. Metallurgically it is a cross between the ferritic and austenitic types possessing several unique qualities. Nominally the steel contains 27 per cent chromium, 4.5 per cent nickel and 1.75 per cent molybdenum. Its corrosion resistance in the annealed condition approaches and in many cases is superior to that of Type 316. This fact, coupled with the lower content of critical alloys, has encouraged its use as an alternate grade. Mechanical properties of the annealed steel are as follows:

Yield Strength (0.2% offset, psi)	80,000
Tensile Strength (psi)	100,000
Elongation (% in 2 inches)	25
Reduction of Area (%)	60
Izod Impact (V-notch, ft-lb)	40
Hardness (Brinell)	230
(Rockwell B)	98

Its physical properties and fabricating qualities closely resemble those of the ferritic types.

Type 329 is unusual in that it can be heat treated to a hardness of 40 to 45 Rockwell C by aging for 12 hours at 1350 F. Unlike the martensitic steels, this grade becomes nonmagnetic when hardened. The hardening of the steel is accompanied by a drop in impact strength. Corrosion resistance, although lowered, is far superior to that of the martensitic grades, permitting the use of this steel where both hardness and corrosion resistance are needed. Ball check valves, valve fittings, pump cylinders and sleeves are representative applications.

The list of new steels also includes Carpenter Stainless No. 10. Developed to overcome the manufacturing difficulties associated with the work-hardening properties of the conventional austenitic stainless steels, this alloy is ideal for all types of parts requiring severe cold heading or upsetting. It is especially recommended for the manufacture of recessed head fasteners, and for use on automatic nut-making machines. A steel high in nickel (16 per cent chromium, 18 per cent nickel), it is confined today to special applications which *cannot* be handled by the standard 18-8 grades.

The chromium-nickel-manganese austenitic stainless steels, familiar during World War II, are being used in increasing quantities. These steels, developed to conserve nickel, contain approximately 18 per cent chromium, 4 per cent nickel, and 6 per cent manganese. The corrosion resistance of these steels is comparable to the standard chromium-nickel types in most corrosives. The chromium-nickel-manganese steels are stronger and have a higher work-hardening rate than the standard Type 302 and 304 analyses. When cold worked to high strengths, they have exceptional toughness and ductility which is particularly desirable in spring applications.

Summary: The demands of a defense economy and the attendant restrictions on the availability of metals in short supply stress the need for intelligent selection and application of these metals. Factors of first importance are corrosion resistance, mechanical requirements, and fabricating qualities; each must be considered in an evaluation of the various grades open to choice. TABLE 12 sums up in brief form the relative workability of the different stainless types.

When a stainless type is considered for a new application, or a changeover is contemplated for an existing product, pitfalls can be avoided and best results assured by a thorough study of the problem. The references listed at the end of this article will aid such a study. Additionally, the counsel of materials engineers or producers of stainless steels should be sought. Their experience and their knowledge of current developments may quickly provide answers otherwise available only through more painful or expensive means.

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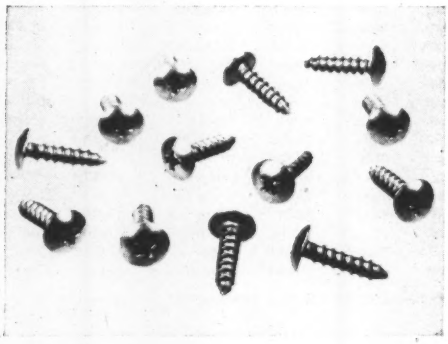
2. *The Book of Stainless Steels*—Edited by Ernest E. Thum, American Society for Metals, Cleveland, Ohio, 1935.
3. Carl A. Zapffe—*Stainless Steels,* American Society for Metals, Cleveland, Ohio, 1949.

When parts to be made from chromium-nickel stainless require severe coining, swaging, or upsetting, fabricating costs will usually be prohibitive. This difficulty arises because the regular grades of 18-8 work harden too rapidly. The solution to this problem came with the recent development of Carpenter Stainless No. 10. Work-hardening is greatly reduced so that recessed head fasteners like those shown here can now be made on automatic machines.



New Standard Consolidates Bolt and Nut Dimensions

SIMPLIFICATION is the keynote of the new unified standard on *Square and Hexagon Bolts and Nuts*. Needless variety has been eliminated by consolidation of types of bolts and nuts that have similar proportions, characteristics, and applications. Previous dual classifications—hexagon bolts and hexagon cap screws, light and regular hexagon nuts—have been replaced by single series. In addition, although past standards covered only principal bolt head and nut proportions, leaving other details to trade practice and individual requirements, the new standard contains complete dimensional specifications and material recommendations.

Important Changes: With the exception of heavy bolts, head dimensions of all former series of hexagon bolts and capscrews have been consolidated into a single dimensional series. To accomplish this consolidation, former across-flats dimensions of the automotive hexagon head bolts or cap screws have been selected as basic for bolts through 9/16-inch diameter, and former across-flats dimensions of the regular hexagon bolts have been selected as basic for bolts of 5/8-inch and larger diameter. Head heights have been made 5/8 of the nominal diameter. A comparison of former and new standard dimensions is shown in TABLE 1.

Table 1—Comparison of Hexagon Bolt Head Dimensions*

Nom. Bolt Size	Old Standard—Reg. Semifin. Across Flats	Old Standard—Reg. Semifin. Head height	Old Standard—Capscrew Across Flats	Old Standard—Capscrew Head height	New Standard—Finished Across Flats	New Standard—Finished Head height
1/4	3/8	5/32	7/16	5/16	7/16	5/32
5/16	1/2	7/32	1/2	11/64	1/2	11/64
3/8	9/16	1/4	9/16	3/8	9/16	1/4
7/16	5/8	9/32	5/8	31/64	5/8	9/32
1/2	3/4	11/32	3/4	3/8	3/4	7/16
9/16	7/8	13/32	13/16	27/64	13/16	23/64
5/8	15/16	25/64	7/8	15/32	15/16	25/64
3/4	1 1/8	15/32	1	9/16	1 1/8	15/32
7/8	1 5/16	9/16	1 1/8	21/32	1 5/16	35/64
1	1 1/2	19/32	1 5/16	3/4	1 1/2	39/64
1 1/8	1 11/16	11/16	1 1/2	27/32	1 11/16	11/16
1 1/4	1 7/8	39/64	1 11/16	15/16	1 7/8	39/64

* All dimensions are in inches

Light and regular series hexagon nuts have also been consolidated. Dimensional proportions of the former light series have been selected as basic for sizes through 5/8-inch diameter with the exception of the 7/16-inch nut which is a modification of both of the former series. For nuts on sizes above 5/8-inch, dimensional proportions of the former regular series are basic. A comparison of former and new dimensional nut proportions is shown in TABLE 2.

Products classified under the new standard are:

Square Bolts; regular

Hexagon Bolts; regular, regular semifinished, finished, heavy, heavy semifinished, and heavy finished.

Hexagon Head Capscrews

Lag Bolts

Set Screws; square head

Square Nuts; regular, heavy

Hexagon Nuts; regular, regular jam, regular semifinished, regular semifinished jam, regular semifinished slotted, finished, finished jam, finished slotted, finished thick, finished thick slotted, finished castle, heavy, heavy jam, heavy semifinished, heavy semifinished jam, and heavy semifinished slotted.

Stove Bolt Nuts

Machine Screw Nuts

The use of the term "finished" in the standard refers always to the quality of manufacture and closeness of tolerance and does not necessarily indicate that surfaces are machined. "Finished hexagon bolts" designates the consolidated series of former automotive hexagon head bolts and close body-toleranced regular semifinished bolts. "Finished hexagon nuts" designates the consolidation of light and regular series of washer-faced or double chamfered nuts. Also, the term "cap screw" has been retained in the range of bolt sizes from 1/4 to 1 1/2 inches for hexagon products having the same proportions and characteristics as the finished bolts.

Design Considerations: The new hexagon bolt head dimensions provide a bearing area under the head

which is 1¼ times the stress area of the threaded section. As a result, across-flats dimensions of the new head are ⅛ to 3/16-inch greater than those for the old cap screw on sizes above ⅝-inch diameter. Similarly, the new hexagon nuts, providing a bearing area equal to the head, are larger across the flats than the light hex nut for sizes above ⅝-inch diameter. These size changes under the new standard should be given consideration on new designs where bolt and nut clearances may become critical.

It is interesting to note that hexagon bolt and nut across-flats dimensions are identical for all diameters with the exception of the 7/16-inch diameter size. Here the nut is 1/16-inch greater than the bolt head.

Designers are to be cautioned in the use of this standard. Although the proportions of square bolts and nuts, heavy bolts, and other products are, with some exceptions, the same as under previous standards, numerous detailed changes have been made in tolerances, nomenclature and general specifications which may affect application or interchangeability. The new products should be carefully compared with present design practice and requirements.

Historical Background: Development of the new standard was initiated in 1947, the aim at that time being to expand the existing standard on bolt head and nut proportions into a comprehensive product standard. Soon after the first draft had been completed and was under consideration, a proposal was received from the British Standards Institution for unification of product dimensions incorporating the new unified screw threads. This proposal ultimately led to British-Canadian-American Conferences in New York and London where unified dimensions for hexagon nuts and bolts were established using existing American Standards as a basis. The responsibility for incorporating the conference recommendations was assigned to the respective standardizing bodies.

In March 1951, a revised American Standard was submitted to industry for comment. Besides incorporating conference recommendations this draft included further changes which combined the light and regular series of nuts as well as the automotive hexagon-head bolt, hexagon-head cap screw and regular close-tolerance bolt. Except for changes in the square nuts and bolts, which were not involved in unification, and editorial changes in the nomenclature of the unified products, the final approved standard is the same as the March 1951 draft.

Thus, the new standard has both national and international significance. In its scope as an instrument of mutual defense, it will permit standard designs of equipment which can be manufactured in any of the three countries. Repair of battle damage or service utilizing bolts and nuts will be facilitated by standardization in production and stocks.

For American industry the new standard provides complete product specifications. New designs can make advantageous use of fasteners that are completely interchangeable. Further benefits include greater economy of manufacture, increased availability of standard bolts and nuts, and improved quality and service of products. Prepared under the sponsorship of the American Society of Mechanical Engineers and the Society of Automotive Engineers, the new standard has been officially designated *American Standard ASA B*18.2-1952.

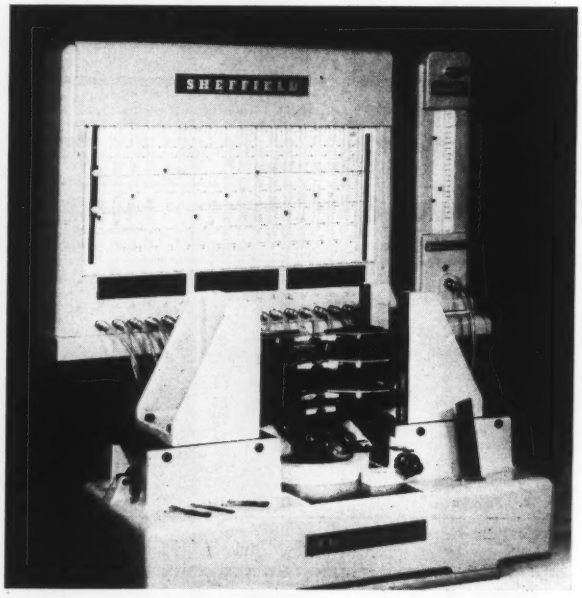
Table 2—Comparison of Hexagon Nut Dimensions*

Nom. Bolt Size	Old Standard—Reg. Semifin. Across Flats	Old Standard—Reg. Semifin. Head height	Old Standard—Light Across Flats	Old Standard—Light Head height	New Standard—Finished Across Flats	New Standard—Finished Head height
¼	7/16	13/64	7/16	3/32	7/16	3/32
5/16	1/2	1/4	1/2	1/8	1/2	17/64
3/8	5/8	5/16	9/16	21/64	9/16	21/64
7/16	3/4	23/64	5/8	3/8	1/16	3/8
1/2	13/16	27/64	3/4	7/16	3/4	7/16
9/16	7/8	31/64	7/8	31/64	7/8	31/64
5/8	1	17/32	15/16	35/64	15/16	35/64
3/4	1 1/8	41/64	1 1/16	39/32	1 1/8	41/64
7/8	1 5/16	3/4	1 1/4	49/64	1 5/16	3/4
1	1 1/2	55/64	1 7/16	7/8	1 1/2	55/64
1 1/8	1 11/16	31/32	1 5/8	63/64	1 11/16	31/32
1 1/4	1 7/8	1 1/16	1 13/16	1 3/32	1 7/8	1 1/16

* All dimensions are in inches

Multiple Air-Gage

DIMENSIONS of jet engine blades can be checked simultaneously at 18 to 26 different points with the Sheffield air-gaging instrument shown. The turbine blade is held in a dovetail fixture, adjustable through vernier control knobs to orient the blade in gaging position. The gaging nozzles are grouped on support plates attached to slide-mounted knees at various levels, so that the float-position pattern on the gage panel gives an indication of contour, thickness, tilt and angle of blade.



Designing Mechanical Computers

Part I–Functions Having Two Variables

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***FOR THE FIRST TIME** it is possible to design practical mechanical computers for involved functions by mathematical methods. Arbitrary functions having as many as five independent variables may be represented within the degree of accuracy desired. With this system, based upon work done under Air Force Contract No. W 33-038 ac-20692, a function generator may be developed which is more economical than a solid cam, especially when small quantities are involved. Mechanisms employing two single variable-function linkages feeding into a linkage multiplier have been successfully tested, confirming the theory. Also, mechanisms for sums-of-functions plus products-of-functions have been built and tested. Although of a highly classified nature, this actual equipment indicates that the theory can be put into practice in a relatively simple manner*

ONE of the persisting problems in machine design is the mechanization of arbitrary, preassigned relationships among the motions of the different parts. Interrelated motions in sewing machines, locomotive-valve gears, or gun predictors are good examples. The cam is one familiar solution to this problem and the linkage is another. Similar devices are based on electrical, hydraulic, and other principles.

Military demands for automatic fire control have forced the development of complicated systems of this kind, which can represent a specified interrelationship of several independent quantities. A ballistic table, for example, expresses the range of a shell in terms of the elevation of the gun, the propelling charge, the form of the shell, the air density, etc. The form of the dependence is far from a simple sum of effects arising from the independent variables separately. Industrial-process control is developing an increasing

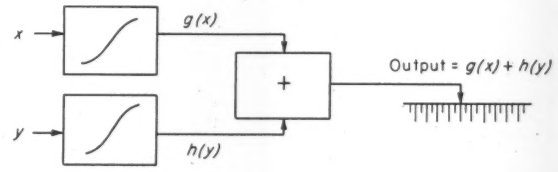

Fig. 1—Block diagram for the sum-of-functions as a single output

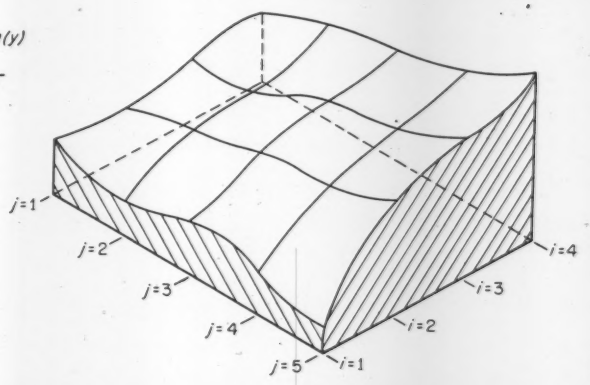

Fig. 2—Isometric view of the illustrative surface $F(x_1,y_1)$. This involved surface can be represented by a block diagram like *Fig.* 3

need for the physical storage of similar mathematical relationships. The interrelated adjustments in a petroleum refinery and the optimum control of an aircraft power plant are examples.

Since a single cam for more than two independent variables cannot be constructed in real space, computer designers have been forced to adopt various unsatisfactory evasions of the problem, such as providing the required functions in multiple-entry tables from which the operator transfers the information to the machine. It is the purpose of this article to present mathematical methods which permit, we believe for the first time, the practical construction of mechanical computers representing arbitrary functions of as many as five independent variables.

These methods are based on the properties of multilinear polynomials. The particular classes which are used in computer design have been termed "function structures." Essentially, the function of many variables is expanded into a rapidly converging series of sums and products of one-variable functions.

This first article is devoted primarily to illustrating these methods on functions of two variables. Although it is always possible to represent a function of two variables by a solid cam, computers based on a function structure are often more economical, especially when small quantities are involved. Also, without the use of solid cams, there will be no problems of undercutting.

The succeeding article will extend these approximating methods to the important case of more than two independent variables, where direct methods are inapplicable, and will discuss the organization of these function structures into practical mechanical computers.

Suppose that a tabulated function of two independent variables is available, and that it is required to reproduce this function in a form involving the variables singly, interrelated only by standard operations such as addition and multiplication. Although such a table is only a collection of numbers, it is conveniently designated as the "function $f(x, y)$," existing only at the points (x_i, y_j). Similarly, "functions $g(x)$ and $h(y)$," of the independent variables singly, exist only at x_i or y_j, respectively. It is assumed that the data are in factorial form, i.e., there are no "holes" in the table. If m values of x and n values of y are given, there will be a value z_{ij} at every point (x_i, y_j) in the rectangular lattice—a total of mn points.

Conventionally, $f(x, y)$ would be expanded in terms of a series of orthogonal functions[1], such as Fourier Series. The result of such an expansion would be:

$$\begin{aligned} f(x,y) = {} & a_0 + a_1\,\phi_1(x) + b_1\,\phi_1(y) + \\ & c_1\,\phi_1(x)\,\phi_1(y) + a_2\,\phi_2(x) + \\ & b_2\,\phi_2(y) + c_2\,\phi_1(x)\,\phi_2(y) + \\ & c_3\,\phi_2(x)\,\phi_1(y) + a_3\,\phi_3(x) + \\ & b_3\,\phi_3(y) + c_4\,\phi_1(x)\,\phi_3(y) + \\ & c_5\,\phi_2(x)\,\phi_2(y) + \cdots \end{aligned} \qquad (1)$$

where the ϕ's are the orthogonal functions (typically sines and cosines). The part of the series in Expression 1 has 21 elements—the three functions ϕ_1, ϕ_2 and ϕ_3 of x, and the same three of y, the ten plus signs (remembering that a_0 is a zero set), and the five multiplications. There are also the 12 disposable constants, the a's, b's, and c's, whose values are adjusted to make the approximating series fit the given function as accurately as possible.

It is plausible that the error involved in approximating $f(x, y)$ will be inversely proportional to the number of disposable constants in the approximating series, and experience has shown this to be true in a general way. From this point of view, it is logical to look for some other form of series, which will have a larger number of adjustable constants and fewer elements. Remembering that $f(x, y)$ exists only at the isolated points x_i and y_j, it is again plausible to consider using approximating functions with this same property. If one were to approximate by

$$f(x_i, y_j) \doteq g(x_i) + h(y_j) \qquad (2)$$

For example, where $g(x_i)$ is simply a column of m numbers corresponding to the m tabular values of x_i and $h(y_j)$ is similarly a column of n numbers corresponding to the tabular values of y, *then each of these numbers is a separate disposable constant.* If $f(x, y)$ is given by a 6×6 table, then the approximating form

[1] A clear, elementary discussion of this process is given in Reference 1 at the end of this article.

Table 1—Illustrative Example of $F(x,y)$

$j=5$	-18.40	+10.91	+18.92	+26.73
$j=4$	-10.96	+ 2.94	+ 8.80	+16.30
$j=3$	- 7.08	+ 1.67	+ 5.22	+10.73
$j=2$	-13.12	- 3.43	- 2.19	+ 5.27
$j=1$	- 5.26	- 8.14	-5.07	- 2.95
y_j / x_i	$i=1$	$i=2$	$i=3$	$i=4$

Table 2—Illustrative Example of $f(x,y)$

$j=5$	-19.94	+ 9.37	+ 17.38	+ 25.19
$j=4$	-12.50	+ 1.40	+ 7.26	+ 14.76
$j=3$	- 8.62	+ 0.13	+ 3.68	+ 9.19
$j=2$	-14.66	-4.97	- 3.73	+ 3.73
$j=1$	- 6.80	-9.68	-6.61	-4.49
y_j / x_i	$i=1$	$i=2$	$i=3$	$i=4$

in Expression 2 has 12 disposable constants, the six numbers forming $g(x_i)$ and the other six which are the column of numbers making up $h(y_j)$, *but only three elements instead of* 21. The three elements required to mechanize Expression 2 are a function unit for $g(x)$, another for $h(y)$, and an adding device, as illustrated in *Fig.* 1. This seven-fold reduction in the number of elements would probably be the difference between a perfectly practical computer, and an impractical monstrosity.

The simple sum of two arbitrary functions used in Expression 2 is rarely flexible enough to approximate a given tabular function with usable accuracy. Once the idea of an arbitrary approximating function whose every value is a separate disposable constant is clear, the next forward step to more complicated algebraic combinations of such functions is easy to take. Approximating functions having eleven elements and $3m$ plus $3n$ disposable constants, such as

$$f(x_i, y_j) \doteq g(x_i) + h(y_j) + g'(x_i)\, h'(y_j) + g''(x_i)\, h''(y_j) \quad \ldots\ldots (3)$$

which involves six functions, two multiplications, and three additions, will often approximate arbitrary functions to the accuracy to which it is usually practical to cut a barrel cam. In Expression 3, the single and double primes indicate *different* arbitrary functions. Applied to a 6 × 6 table, this approximation provides 36 disposable constants with eleven elements[2]; applied to a 12 × 12 table, the same eleven elements provide 6 × 12 = 72 disposable constants. Because a 12 × 12 table can describe a more complicated function, however, the degree of fit is likely to be less close, in spite of there being twice the number of constants to adjust.

Table 3—Illustrative Example of the Sum-of-Functions

+8.00 j=5	-19.94 - 4.50 -15.44	+9.37 +7.25 +2.12	+17.38 +11.60 + 5.78	+25.19 +17.68 + 7.51
+2.73 j=4	-12.50 - 9.77 - 2.73	+1.40 +1.98 -0.58	+ 7.26 + 6.33 + 0.93	+14.76 +12.41 + 2.35
+1.10 j=3	- 8.62 -11.40 + 2.78	+0.13 +0.35 -0.22	+ 3.68 + 4.70 - 1.02	+ 9.19 +10.78 - 1.59
-4.91 j=2	-14.66 -17.41 + 2.75	-4.97 -5.66 +0.69	- 3.73 - 1.31 - 2.42	+ 3.73 + 4.77 - 1.04
-6.90 j=1	- 6.80 -19.40 +12.60	-9.68 -7.65 -2.03	- 6.61 - 3.30 - 3.31	- 4.49 + 2.78 - 7.27
$h(y_j)$ / $g(x_i)$	-12.50 i=1	-0.75 i=2	+ 3.60 i=3	+9.68 i=4

The apparent value of this new approach has been borne out in practical experience. Linkage and other analogue computers based on this theory work in the way one would expect from the argument outlined previously[3]. The remainder of this article will be devoted to the theory and the practical methods for calculating the approximating functions $g(x_i)$, etc., from a given tabulated function.

Throughout the following, the symbol f denotes a function whose average value is zero, i.e.,

$$\sum_i \sum_j f(x_i, y_j) \equiv 0 \quad \ldots\ldots (4)$$

A capital letter, e.g., $F(x_i, y_j)$, denotes a function whose mean is not necessarily zero. If the mean of a function is not zero, it can always be made so merely by subtracting the mean value from each given value of the function. Such subtraction does not change the shape of the original function, and it leads to more convenient arithmetic. Some proofs, related to the methods given here, become extremely complicated if the original function does not have zero mean.

The calculation of adustable functions is relatively simple. Choosing, for example, the least-squares criterion of approximation, the functions $g(x)$ and $h(y)$ in $f(x, y) \doteq g(x) + h(y)$ would be so adjusted that

$$R^2 = \sum_{i=1}^{i=m} \sum_{j=1}^{j=n} \left\{ f(x_i\ y_j) - \left[g(x_i) + h(y_j) \right] \right\}^2 = \text{a minimum} \quad \ldots\ldots (5)$$

namely, the sum of the squares of the errors of approximation $R(x_i, y_j)$ at the separate points (x_i, y_j), will be a minimum. Solution of this variation problem gives

$$g(x_i) = \left(\frac{1}{n} \right) \sum_j f(x_i, y_j) \quad \ldots\ldots (6a)$$

and

$$h(y_j) = \left(\frac{1}{m} \right) \sum_i f\ (x_i, y_j) \quad \ldots\ldots (6b)$$

as the *best* functions for $g(x)$ and $h(y)$ in Expression 2. Complete derivation of these equations is given in the Appendix. In the longer expansion

$$f(x, y) \doteq g(x) + h(y) + g'(x)\, h'(y) \quad \ldots\ldots (7)$$

the two new functions $g'(x)$ and $h'(y)$ are calculated from:

$$R(x_i, y_j) = f(x_i, y_j) - [g(x_i) + h(y_j)] \quad \ldots\ldots (8)$$

[2] Readers whose algebra must be kept well oiled will recognize that the 36 disposable constants in this case are sufficient to fit this—or any other—approximating function to the given function exactly.

[3] The normal process of designing an analog function unit involves passing the output of the function unit through several points of the desired curve (Cf. Refs. 2, 3, and 4), so that fits to the arbitrary functions involve no difficulties. A more careful discussion of the consequences of this interpolation is given at the end of this article.

Table 4—Summary of Iterative Results

Initial estimate of $h'(y_j)$	−3.5000	−0.7500	−0.7500	+1.0000	+4.0000
1st solution for $g'(x_i)$	−3.7115	+0.4824	+1.2581	+1.9690	
1st solution for $h'(y_j)$	−3.4017	−0.7688	−0.7622	+0.8039	+4.1293
2nd solution for $g'(x_i)$	−3.7136	+0.4872	+1.2652	+1.9593	
2nd solution for $h'(y_j)$	−3.4011	−0.7692	−0.7621	+0.8032	+4.1298
3rd solution for $g'(x_i)$	−3.7136	+0.4872	+1.2652	+1.9592	
3rd solution for $h'(y_j)$	−3.4012	−0.7693	−0.7621	+0.8032	+4.1298

according to:

$$g'(x_i) = \frac{\sum_j R(x_i, y_j)\, h'(y_j)}{\sum_j [h'(y_j)]^2} \quad \ldots\ldots (9a)$$

$$h'(y_j) = \frac{\sum_i R(x_i, y_j)\, g'(x_i)}{\sum_i [g'(x_i)]^2} \quad \ldots\ldots (9b)$$

These equations result from the solution that minimizes the sum of the squared-errors in the approximation

$$R(x_i, y_j) \doteq g'(x_i)\, h'(y_j) \quad \ldots\ldots (10)$$

In the case of sum-functions, Expressions 6*a* and 6*b*, one has merely to substitute into the formulas and solve. Here, however, an iterative solution is required. To find $g'(x_i)$ and $h'(y_j)$ from Expressions 9*a* and 9*b*:

1. Select the set of n values $h'(y_j)$ arbitrarily, and solve for the set of m values $g'(x_i)$, using Expression 9*a*
2. With this last set of values $g'(x_i)$, solve for $h'(y_j)$, using Expression 9*b*
3. With this last set of values $h'(y_j)$, solve for $g'(x_i)$, using Expression 9*a*
4. Proceed in this manner; iterate until the sets of values $g'(x_i)$ and $h'(y_j)$ converge to steady values, to the required number of figures
5. It is advisable to carry extra digits (2 or so) when computing most iterative routines or else the iteration may converge to cyclical values.

The derivation of the Expressions 9*a* and *b* is indicated in the Appendix.

Writing Expression 10 in equation form:

$$R(x_i, y_j) = g'(x_i)\, h'(y_j) + R'(x_i, y_j) \quad \ldots\ldots (11)$$

the function $R'(x_i, y_j)$ can now be approximated in turn by a second product

$$R'(x_i, y_j) \doteq g''(x_i)\, h''(y_j) \quad \ldots\ldots (12)$$

thus giving the six functions in the approximating form of Expression 3. This process may be continued to form an infinite sum-of-products series

$$f(x_i, y_j) = g(x_i) + h(y_j) + g'(x_i)\, h'(y_j) + g''(x_i)\, h''(y_j) + \quad \ldots\ldots (13)$$

which is convergent, i.e., the addition of another product term guarantees that the next residual will be less than the previous one. In practical problems, $R''(x_i, y_j)$ will usually be much smaller than $R'(x_i, y_j)$, say one-fifth to one-tenth the size of R', and so on ($R''' << R''$, etc.). That is, the series in Expression 13 usually converges very rapidly, and thus a small number of terms will result in a good approximation to $f(x_i, y_j)$. This is fortunate from the point of view of computer design because it makes for a small number of components. The number of components which is required to mechanize any mathematical expression is, in general, directly proportional to the number of terms or components in the expression.

A great many other structures can also be imagined. None of the other structures has proved very useful thus far, however. Formulas for almost any structure can be derived by the methods of the Appendix.

It is possible, for instance, to form functions of $f(x, y)$, such as in a generalized case of Expression 2:

$$f(x_i, y_j) \doteq [g(x_i) + h(y_j)]^P \quad \ldots\ldots (14)$$

Here, all one has to do to find $g(x_i)$ and $h(y_j)$ is to take the P^{th} root of $f(x_i, y_j)$ and then use this new function as the f in Expression 2. This is a special case wherein it is sometimes better to add a constant to the original function in order to make all values positive prior to taking the P^{th} root. That is, it may not be advisable that the function, f, in Expression 14 have zero mean, depending on the problem at hand.

Expressions 6*a* and *b* suffice to find g and h. It is then necessary to raise the sum $(g + h)$, to the P^{th} power to approximate the $f(x, y)$ of Expression 14. Additional mechanisms are of course required to do

ble 5—Illustrative Example of the Product-of-Functions

+4.13 $j=5$	-15.44 -15.32 - 0.12	+2.12 +2.02 +0.10	+5.78 +5.25 +0.53	+7.51 +8.09 -0.58
+0.80 $j=4$	- 2.73 - 2.97 + 0.24	-0.58 +0.39 -0.97	+0.93 +1.02 -0.09	+2.35 +1.57 +0.78
-0.76 $j=3$	+ 2.78 + 2.82 - 0.04	-0.22 -0.37 +0.15	-1.02 -0.97 -0.05	-1.59 -1.49 -0.10
-0.77 $j=2$	+ 2.75 + 2.86 - 0.11	+0.69 -0.38 +1.07	-2.42 -0.98 -1.44	-1.04 -1.51 +0.47
-3.40 $j=1$	+12.60 +12.61 - 0.01	-2.03 -1.67 -0.36	- 3.31 - 4.32 +1.01	-7.27 -6.66 -0.61
$h'(y_j)$ / $g'(x_i)$	- 3.71 $i=1$	+0.49 $i=2$	+1.27 $i=3$	+1.96 $i=4$

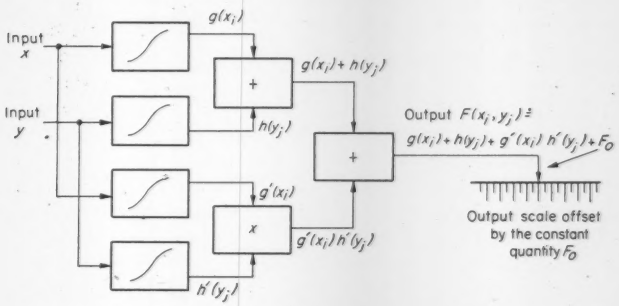

Fig. 3—Illustrative block diagram. Two flat cams, a space cam and an adding mechanism would produce the desired output motion

this. The designer can use other functions of $f(x, y)$ in addition to roots and powers. Any function of $f(x, y)$, such as sine, cosine, etc., whatever function seems to promise success, can be attempted. Multiple-valued solutions may give trouble. If both the selected function and its inverse are single-valued, the process will be straightforward. Always, however, after g and h are found, the inverse function must be applied to their sum in order to approximate the original f.

As a practical example, consider TABLE 1. To operate on this function, first subtract the mean value of table, $F_0 = 1.54$ from each $F(x_i, y_j)$.

$$F_0 = \frac{1}{mn} \sum_i \sum_j F\ (x_i, y_j) \quad \ldots\ldots (15)$$

This does not change the shape of the original function. The result of this subtraction is $f(x_i, y_j)$, TABLE 2, and the mean value, f_0, of this table is zero. The "variance" of TABLE 2 is

$$V = \sum_i \sum_j f^2\ (x_i, y_j) \quad \ldots\ldots (16)$$

namely 2494.33. This is a measure of the amplitude or amount of variation in the table.

If TABLE 2 is approximated by the sum-of-functions in Expression 2, there result the values of $g(x_i)$ and $h(y_j)$ shown on the borders of TABLE 3. These are calculated from Expressions 6*a* and 6*b*. In the body of this table, the top figure in each box is $f(x_i, y_j)$ from TABLE 2; the middle figure is $g(x_i) + h(y_j)$, and the lowest figure is the difference $R(x_i, y_j)$, see Expression 8. The variance of the residual, namely

$$\sum_i \sum_j R^2\ (x_i, y_j) \quad \ldots\ldots (16a)$$

is 589.88, a rather large value.

Now, if $R(x_i, y_j)$ is approximated by a product-of-functions in Expression 10, TABLE 4 shows the program of iterative convergence on $g'(x_i)$ and $h'(y_j)$ using Expressions 9*a* and 9*b*. TABLE 5, bordered by $g'(x_i)$ and $h'(y_j)$, shows $R(x_i, y_j)$, $g'(x_i)\ h'(y_j)$ and $R'(x_i, y_j)$, by reading down in order in each box. The variance of this second residual is reasonably small:

$$\sum_i \sum_j [R'(x_i, y_j)]^2 = 7.27 \quad \ldots\ldots (17)$$

In reproducing a table based on natural, physical phenomena, the residuals will generally be much smaller, relatively, than they are in this example. The illustrative function taken here contains random elements, purposely introduced so that the function would be difficult to approximate simply.

If TABLE 1 is the result of experimental measurements, these results are interpreted as meaning that the causes x and y contribute independently to the result $F(x_i, y_j)$, according to the forms of g and h. The causes x and y also interact multiplicatively, to contribute to the result $F(x_i, y_j)$, according to the forms of g' and h'. This information would, in turn, support conclusions about the dominating physical processes.

If, on the other hand, $F(x_i, y_j)$ is to be represented by a physical analog, then the results of this analysis indicate that the rather involved surface of *Fig.* 2 (which would be difficult to cut as a barrel cam) can be represented by a function generator constructed according to the block diagram of *Fig.* 3, with a residual variance of 7.27.

Use of sums and products of functions to replace a solid cam allows the question of undercutting to be completely avoided. The system can usually be designed so that all solid cams are eliminated. Thus there will not be a cam follower riding on a surface,

hence no undercut problem.

The diagram of *Fig.* 3 need not be followed literally. In this example, for instance, flat cams could be used to reproduce $g(x)$ and $h(y)$, and then a space cam could be used to reproduce $R(x, y)$, rather than to approximate $R(x, y)$ by $g'(x)\ h'(y)$. Here, two flat cams, a space cam, and two adding mechanisms would be required to form $F(x, y)$. This system would lead to an exact reproduction of $F(x, y)$, except for errors introduced by tolerances. In this case, the tolerances on the space cam would be loose compared to what would be required if a space cam were built to reproduce the entire $F(x, y)$. Looser space-cam tolerances would be brought about since the space cam would be required to reproduce only a small part of the total $F(x, y)$. Many design variations of this type can be found, depending on the problem at hand.

A word about the use of variance as a measure of the amplitude of a tabular function may be useful. The great advantage of variance is that it is additive:

$$\sum_i \sum_j f^2(x_i, y_j) = \sum_i \sum_j [g(x_i) + h(y_j)]^2 + \sum_i \sum_j R^2(x_i, y_j) \quad (18a)$$

$$\sum_i \sum_j f^2(x_i, y_j) = \sum_i \sum_j [g(x_i) + h(y_j)]^2 + \sum_i \sum_j [g'(x_i)\ h'(y_j)]^2 + \sum_i \sum_j [R'(x_i, y_j)]^2 \quad (18b)$$

and so on. This is not the case with any other independent measure of the amplitude or size of a function. Although there is no direct connection between variance and the mean of the absolute deviation from zero, root-mean-square values are proportional to the square roots of the variances. In the preceding example, the ratio of the root-mean-square amplitude of $R'(x_i, y_j)$ to that of $f(x_i, y_j)$ is $\sqrt{7.27/2494.33} = 5.40$ per cent.

In connection with the seemingly necessary trial-and-error procedures discussed, it would be helpful if "recognition" techniques were available; i.e., if some relatively simple, perhaps graphical, methods could be developed which would give the designer some hint as to which structures might be most applicable for reproduction of a given function. Simple cases can be recognized by plotting the data in various ways. Beyond this, however, not much can be done, except by trial and error. The problem of recognition of closely-approximating structures buried in a mass of tabular data is a problem akin to factoring, and as such may allow no reasonable solution.

In conclusion, a word should be said about interpolation. After a given function (tabular) has been expanded into sums and products, the next step is to mechanize the results in the form of a machine. When this is done, the result will be a continuous function (when the ordinary analogue methods are used). In this case, the machine has been designed to interpolate among the only known values—the initially given tabular values. The designer must choose the interpolating functions as he designs the machine; in other words, he must add information to the system. He can do this in either of two ways:

1. If more facts are known about the physical system in question, other than those given in the initial table, he can make use of those facts when he selects his interpolation functions, or
2. He can select the interpolation functions arbitrarily, choosing those which are easiest to incorporate into his design.

The choice between these two courses, or some combination of them, depends on the design problem at hand.

In the succeeding and concluding article of this series, approximation methods of designing generators for more than two independent variables will be discussed. The article will show how these function structures can be developed into practical mechanical computers.

Appendix

To illustrate the derivation of the formulas which have been given in the body of the text, two derivations are given here. Derivation for Expression 2 in the text, starts with the equation

$$f(x_i, y_j) = g(x_i) + h(y_j) + R(x_i, y_j) \quad (A\text{-}1)$$

Rearranging, squaring, and summing over i and j result in

$$\sum_i \sum_j [f(x_i, y_j) - g(x_i) - h(y_j)]^2 = \sum_i \sum_j R^2(x_i, y_j) = R^2 \quad (A\text{-}2)$$

which defines R^2. The least-square condition is that that variation of R^2 be zero:

$$\delta R^2 = 0 \quad (A\text{-}3)$$

The variation of R^2 with respect to $g(x_i)$, for instance, is

$$[\partial/\partial g(x_i)]\ R^2 = [\partial/\partial g(x_i)] \sum_i \sum_j [f^2(x_i, y_j) + g^2(x_i) + h^2(y_j) - 2g(x_i)\ f(x_i, y_j) - 2h(y_j)\ f(x_i, y_j) + 2g(x_i)\ h(y_j)] \quad (A\text{-}4)$$

which must vanish. The first, third, and fifth terms of this derivative are zero, since they do not contain $g(x_i)$. The remaining terms reduce to

$$-2\sum_j f(x_i, y_j) + 2\sum_j g(x_i) + 2\sum_j h(y_j) = 0 \quad (A\text{-}5a)$$

$$g(x_i) = (1/n)\sum_j [f(x_i, y_j) - h(y_j)] \quad (A\text{-}5b)$$

since the sum of $g(x_i)$ over j is $ng(x_i)$. Similarly,

$$h(y_j) = (1/m)\sum_i [f(x_i, y_j) - g(x_i)] \quad (A\text{-}6)$$

But the sum of $g(x_i)$ over i, for example, is a constant G, hence

$$h(y_j) = (1/m)\ [\sum_i f(x_i, y_j) - G] \quad (A\text{-}7a)$$

$$g(x_i) = (1/n)\ [\sum_j f(x_i, y_j) - H] \quad (A\text{-}7b)$$

If Expression *A7a* is summed over j, and *A7b* over i, and the condition is imposed that

$$\sum_i \sum_j f(x_i, y_j) \equiv 0 \qquad (A\text{-}7c)$$

then

$$\sum_j h(y_j) = H = (1/m) \sum_i \sum_j f(x_i, y_j) - (1/m) \sum_j G$$
$$= -(n/m) G \qquad (A\text{-}8a)$$

$$\sum_i g(x_i) = G = -(m/n) H \qquad (A\text{-}8b)$$

If this imposed condition is not met, it can always be made so merely by taking the average value of the original function and subtracting it from each $f(x_i, y_j)$ —cf., the illustrative numerical example and Expression 4 in the text.

Since any values of G and H, satisfying Expressions $A8$, satisfy Expressions $A6$ and $A5$, one value may be assigned arbitrarily. If we set $G \equiv 0$, then $H = 0$, and substitution into Expressions $A7$ gives

$$g(x_i) = (1/n) \sum_j f(x_i, y_j) \qquad (A\text{-}9a)$$

$$h(y_j) = (1/m) \sum_i f(x_i, y_j) \qquad (A\text{-}9b)$$

These are Expressions 6*a* and *b* in the text. The meaning of Expressions $A9$ is that, if $f(x_i, y_j)$ is a table of n rows and m columns, then $g(x_i)$ is simply the average of the numbers in the i^{th} column, while $h(y_j)$ is the average of the numbers in the j^{th} row. These values of $g(x_i)$ and $h(y_j)$ ensure that R^2 is a minimum, in comparison to any other approximation by the sum of two arbitrary functions.

Expressions $A9$ and $A1$ have long been used by statisticians for the interpretation of experimental data, under the term "analysis-of-variance.' The special statistical properties of Expression $A1$ have obscured its value from the point of view of this article, however.

For the product-of-functions expansion, the equation analogous to Expression $A1$ is

$$R(x_i, y_j) = g'(x_i)\, h'(y_j) + R'(x_i, y_j) \qquad (A\text{-}10)$$

namely, the structure of the approximation in Expression 10 in the text. By the same procedure as above,

$$\delta(R')^2 = \delta \sum_i \sum_j [R(x_i, y_j) - g'(x_i)\, h'(y_j)]^2 = 0 \qquad (A\text{-}11)$$

$$[\partial/\partial g'(x_i)](R')^2 = 0 = -\sum_j R(x_i, y_j)\, h'(y_j) + \sum_j g'(x_i)[h'(y_j)]^2 \qquad (A\text{-}12a)$$

$$g'(x_i) = \frac{\sum_j R(x_i, y_j)\, h'(y_j)}{\sum_j [h'(y_j)]^2} \qquad (A\text{-}12b)$$

Precisely similar arguments lead to

$$h'(y_j) = \frac{\sum_i R(x_i, y_j)\, g'(x_i)}{\sum_i [g'(x_i)]^2} \qquad (A\text{-}12c)$$

Expressions $A12b$ and *c* are identical to 9*a* and *b* of the text.

These two arguments illustrate the method, and most of the pitfalls, involved in deriving the calculating procedures for almost any structure. They can be extended to any number of independent variables without essential change.

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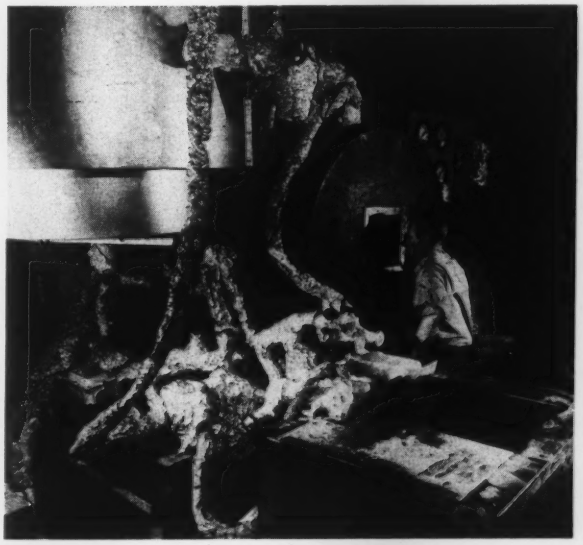
Cold Test for Jet Accessories

JET engine accessories must function at temperatures as low as 67 degrees below zero. Each new design is subjected to cold tests in this cylindrical chamber at Westinghouse Aviation Gas Turbine Div., shown testing a fuel pump at high-altitude temperatures. The fuel tank containing the alcohol being circulated through the fuel pump is cooled with powdered dry ice in the cold-chest in the foreground. Fuel lines are insulated with crinkled aluminum foil pressed into place by hand, permitting quick and simple changes in the test setup.



"Alert, aggressive research, backed by the necessary dollars and authority needed to succeed in the task, alone can make possible the great increase in output per man hour worked which must come if we are to reach the goals upon which our sights in the United States have been set."—DR. H. E. FRITZ, *vice president, B. F. Goodrich Co.*

CONTEMP

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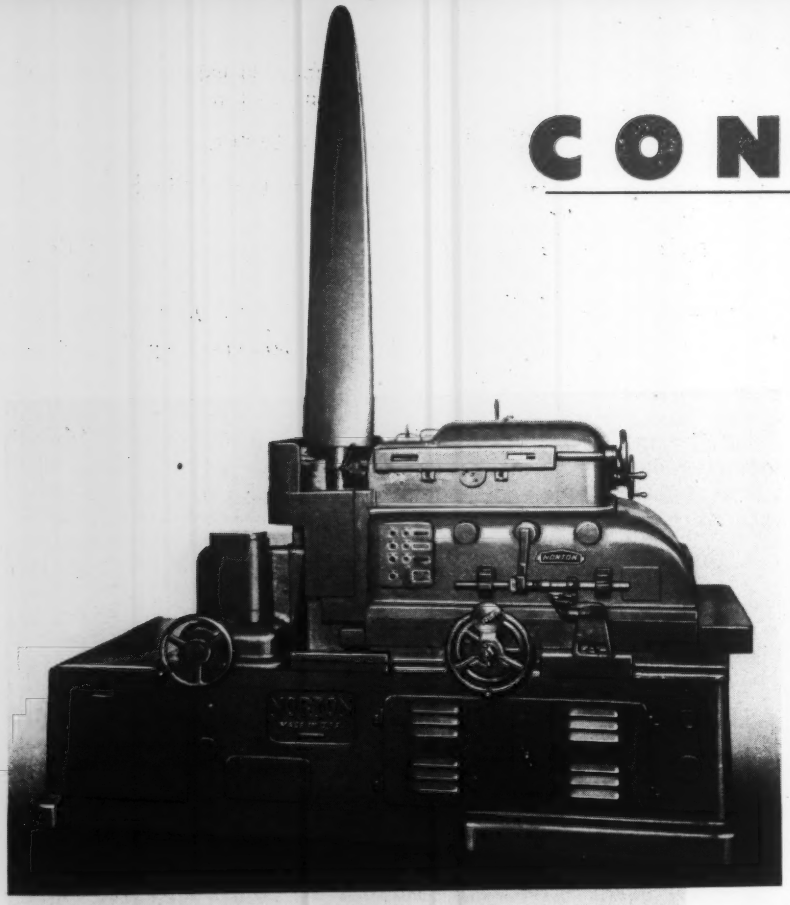
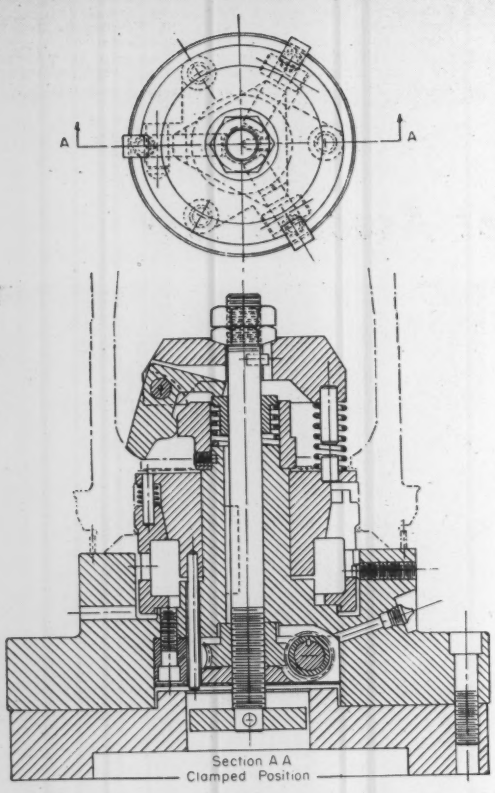




Grinder Chuc

VERTICAL grinding wheel and work spindles in the Norton propeller blade hub grinder, left, minimize work loading and set-up time and reduce grinding time since this arrangement nullifies inherent work deflection characteristics—a critical speed-governing factor in precision grinding. Desirably so, floor space occupied by the vertical spindle machine is conservative and independent of propeller length.

Arrangement of the principal mechanisms is illustrated in the developed cross-sectional drawing, right, below. The work holding spindle is carried in a dovetail slide and is adjustable vertically through a geared feedscrew either by power-feed or hand operation. This spindle is key driven by a sliding fit V-belt pulley carried in a separate ball bearing assembly mounted in the bed of the machine. Concentricity of the outside hub diameters with the finished bore is assured by a special internal expanding chuck, left, which simultaneously centers and clamps the blade endwise.

The grinding wheel spindle, right, above, is powered by a built-in 10-hp shell-type motor, equipped with a cooling fan and ducted for air circulation. Both spindles, built by Pope Machinery Corp., are equipped with SKF double-row precision roller bearings. The inner races of these bearings are adjustable on tapered seats of the spindles to control bearing preload at assembly. Special precision ball thrust bearings, also preloaded, maintain accurate position of the spindles endwise. All bearings in the spindles are prelubricated and labyrinth-sealed to retain the lubricant and exclude coolant, dust, and dirt.

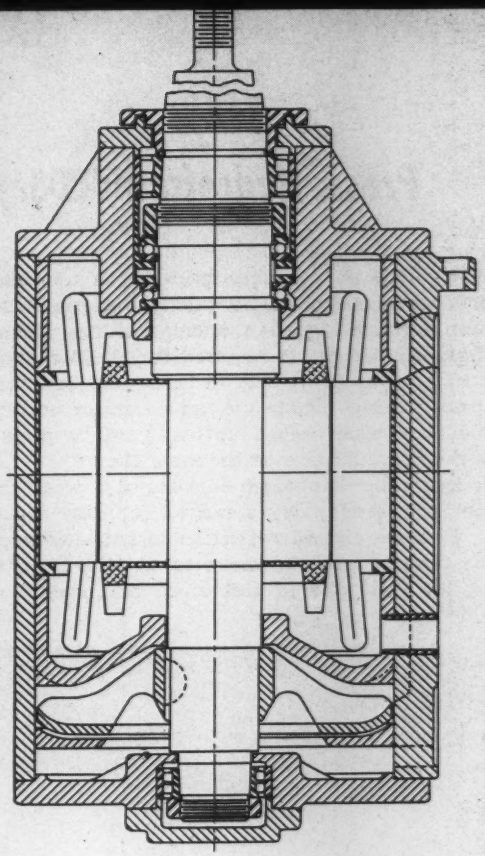
Face of the grinding wheel is trued with a diamond mount attached to the vertical dovetail spindle slide, and a radius dresser

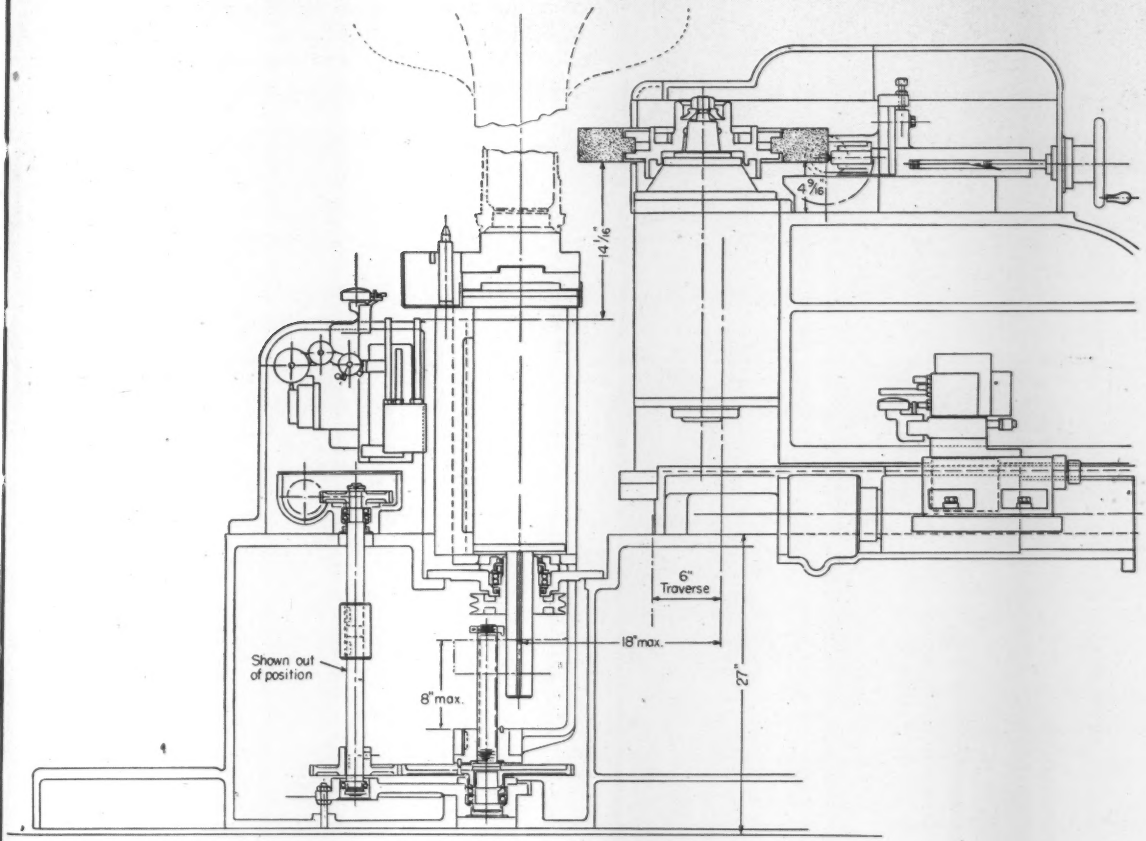
RARY

SIGN

opeller Blades Vertically

is built permanently into the wheelhead. To facilitate positioning the spindles for grinding the various diameters and shoulder locations, dial indicator attachments are provided. The wheelhead is equipped with cushioned hydraulic rapid infeed and automatic grinding feed. Handwheel control is provided for advancing the wheel in increments of 0.0001-inch work diameter reduction.

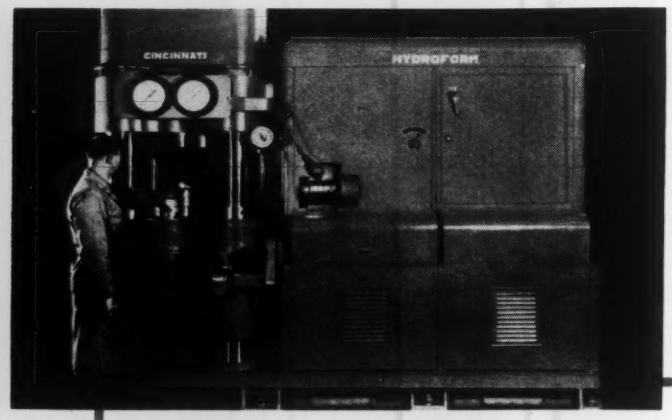




Press Hydroforms Deep Parts

OPERATING on a unique principle, a new metal forming machine known as the Hydroform, below, has been developed by the Cincinnati Milling Machine Co. Only a male die is required for the forming of parts ranging up to ⅜-inch in thickness. Instead of the usual mating female die, an overhead universal flexible diaphragm backed up by hydraulic pressure forms the metal blank over the male die.

The hydraulic diaphragm consists of a wear sheet and an inner-sealing ply arranged for easy replacement. Because excessive friction is not encountered in this forming process, die wear is at a minimum. Hence, low cost dies of soft steel, cast iron, brass, aluminum, Kirksite, and even hard wood can often be used satisfactorily.

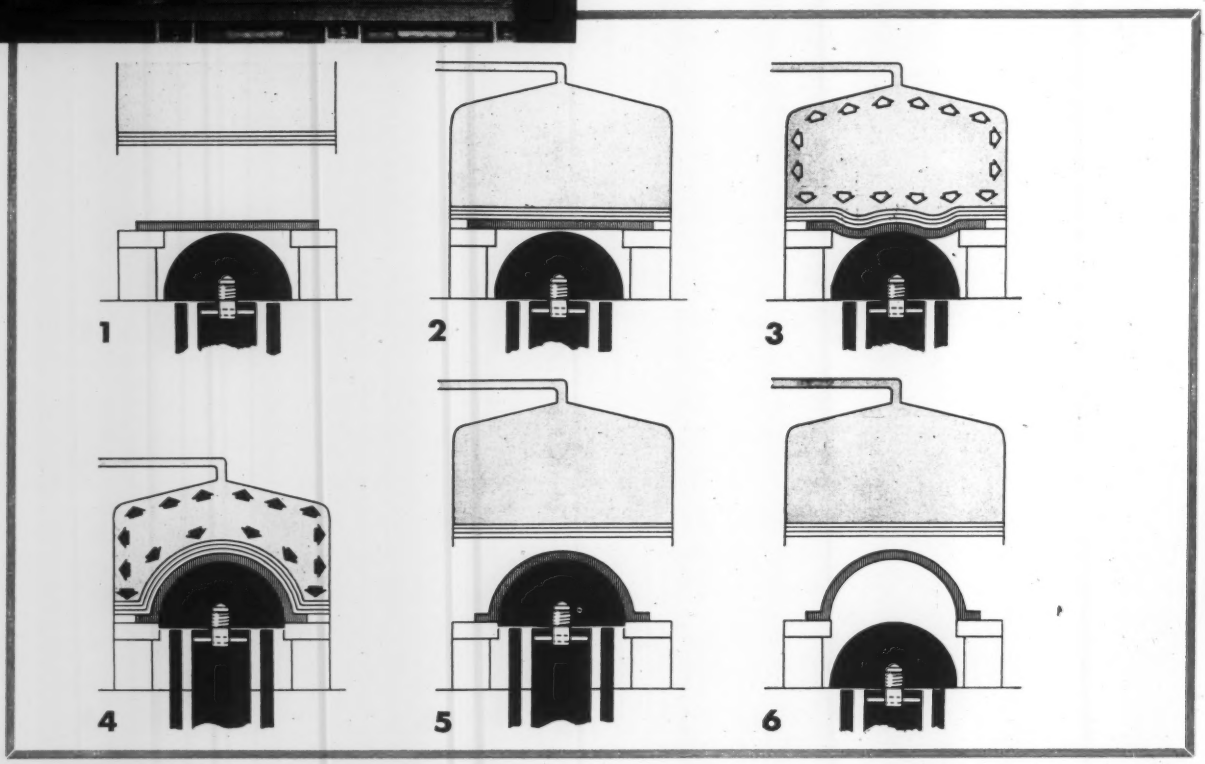


Operating sequence of the new machine is illustrated below. With the blank clamped on a draw ring to control metal flow, hydraulic pressure is admitted in the fluid dome to support the flexible die member. As a ram carrying the male die moves upward, pressure is increased automatically in the dome, up to 15,000 psi if desirable, causing the blank to envelope the male form. Stripping is accomplished automatically when the ram is retracted.

High pressure for the forming operation is secured through a booster circuit operated from a main pump pressure of 8000 psi. The hydraulic system is equipped with Cuno filters and Ross heat exchangers to insure efficient performance. Manual and automatic cycle controls are provided with safety interlock arrangements to safeguard the operator and machine.

The 12-inch (blank diameter) model illustrated has a 7-inch draw capacity and a total drive motor rating of 73 horsepower. All electrical and hydraulic equipment is self-contained in this machine for floor-level installation.

Another model for up to 26-inch diameter blanks and 12-inch draw depth has a total drive motor rating of 158 horsepower and requires pit provision for installation.



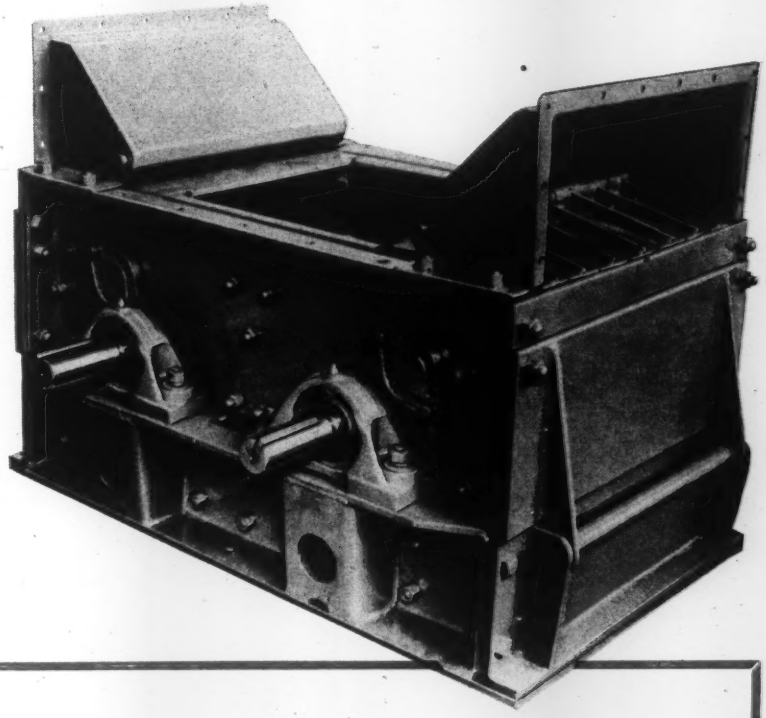
Crusher Ejects Tramp Iron

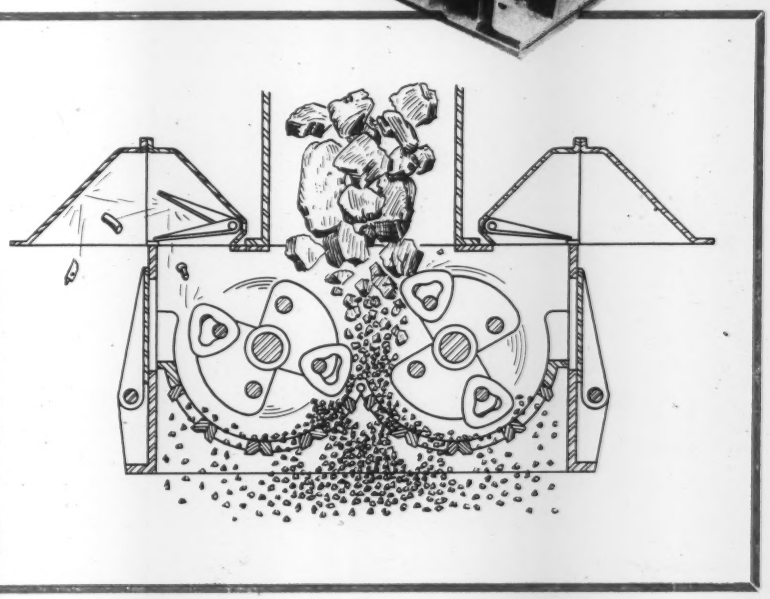
SELF-PROTECTION against damage from tramp iron is designed into the Knittel-type materials crusher, right, below. This feature is accomplished by a series of normally closed gate fingers which open automatically under the impact of foreign metal objects, diagram, below, and deflect them into a scrap chute. Undesirable and damaging materials entering the crusher are accelerated toward the scrap chute through contact with whirling gangs of triangular steel sectors, below.

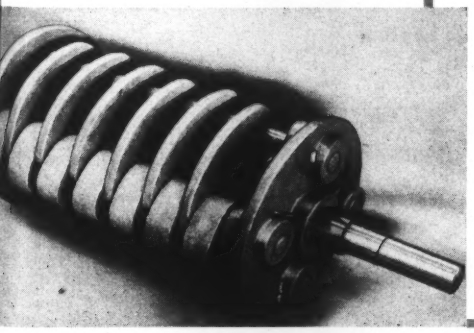
Driven at high speed by direct coupled motors, the loosely mounted sectors are free to recoil under impact with uncrushable objects, thus preventing damage to the crusher. Because of their triangular shape, the least worn or heaviest sides of the sectors automatically are positioned outward near the sizing grates by centrifugal force. Also by virtue of the triangular shape, the corners or points of the sectors lead into the infeeding bulk material resulting in desirable primary splitting or cracking rather than immediate pulverization.

Because of severe operating conditions, the sectors and other wearable parts such as the gratings are cast of manganese steel, which actually becomes tougher under impact. Carried in SealMaster heavy-duty ball bearings, the rotor shafts are chrome nickel steel with keyed extensions for motor couplings.

Some typical materials reduced by this type crusher are: coal, peat, glass, lime, steel turnings, salt, coke, and gravel. Single-rotor crushers similar to the double-rotor machine illustrated also are made by the builders of this machine, the Stephenson-Adamson Mfg. Co.







Hydraulic Bag Pressurizes Press Pad

SIMPLIFIED and economical construction is achieved in a prototype rubber pad forming press, below, by clever utilization of an inflatable elastic bag to pressurize the rubber pad. Schematic cross-sectional drawing, right, below, shows the operating principle of the new press which was developed under the direction of O. A. Wheelon by Douglas Aircraft Co. Inc. particularly for forming relatively long and shallow channel sections, insert, below.

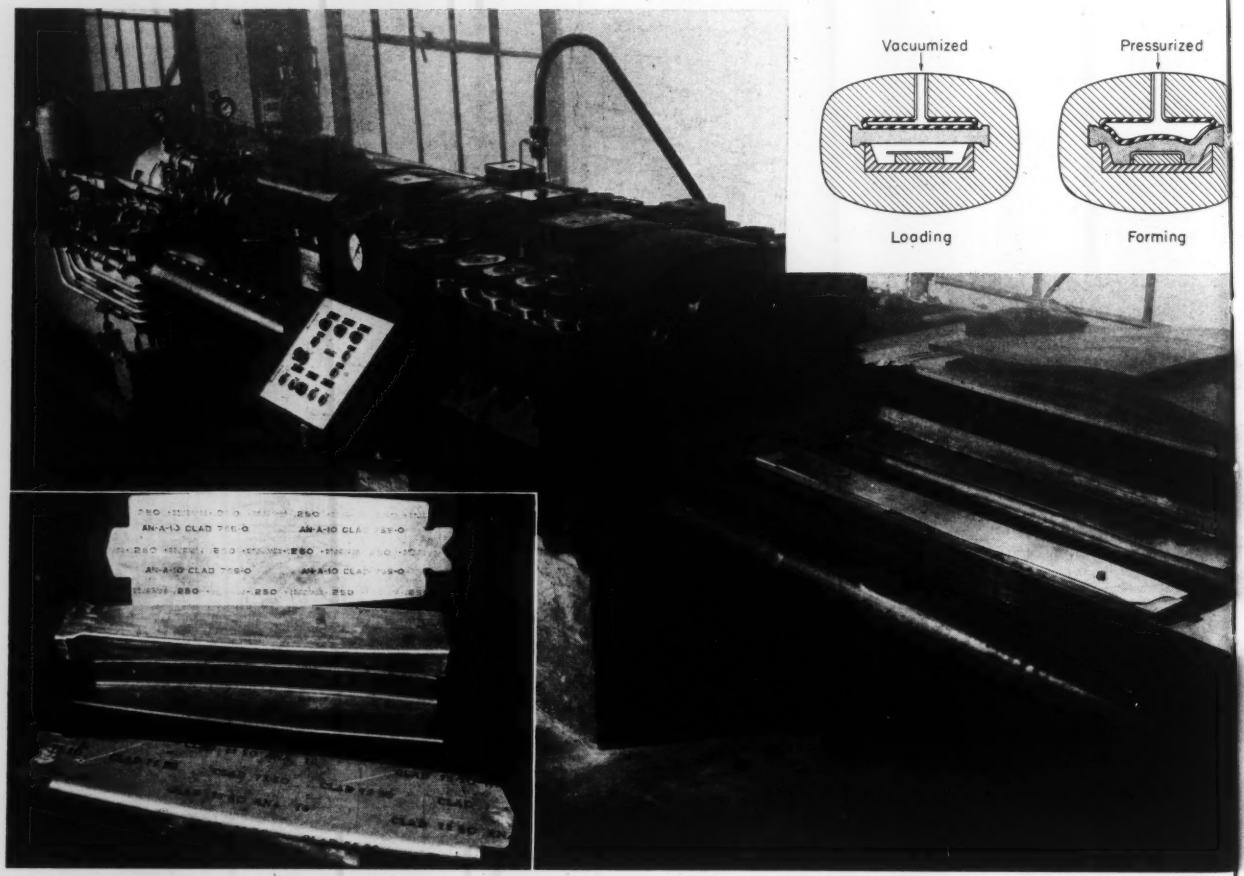
Unlike conventional single-acting presses, the Wheelon press has no moving parts except a pair of traversing bed plates for transporting two forming die setups alternately into pressing position under the forming pad. The dual setup arrangement enables maximum use of the press since one bed plate can be loaded while the other is under compression.

In contrast with the usual pit foundation requirements of previous machines for similar purpose, the compactly designed new press requires a concrete mounting base 20 inches above floor level for working convenience.

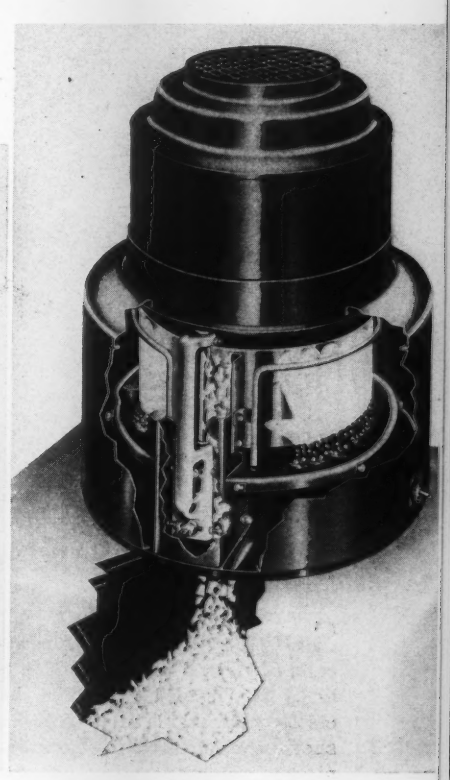
Rated tonnage of the press at maximum operating pressure of 5000 psi is 2500 tons on a platen area 20 by 50 inches. Cycle pressures may be varied from zero to maximum by selective hydraulic control.

Hydraulic power to inflate the bag is supplied from a two-stage pump driven by a 30-hp motor. On reaching a predetermined pressure the pumps are unloaded automatically and bag decompression is effected through a surge valve for a short time interval. Oil remaining in the bag is then pumped out, lifting the pad and bag clear of the work. A vacuum switch senses the completion of this phase of operation and energizes the hydraulic traverse control to shift the die tables.

The control circuit also is interlocked electrically to co-ordinate table movement and to prevent pressurization in the event of improper table location. Total cycle time for a typical setup in the machine is 44 seconds. Manufacturing and marketing license for the Wheelon press has been issued by Douglas to the Verson Allsteel Press Co.



Freezer Makes Flaked Ice



CLEAR small curved ice flakes of minimum air and mineral salt content are produced continuously by a unique process in the new York-FlakIce automatic ice maker, right. Water is pumped from a supply sump, extreme right, and sprayed onto the vertical surface of a slowly revolving stainless steel refrigerated drum.

A solid layer of ice builds up gradually on the highly polished surface of the drum and is harvested at a discharge station by a precision-cast manganese bronze spiral cutter. A collector blade near the cutter insures the removal of all flakes thus produced and directs them into a porcelain-enameled discharge chute.

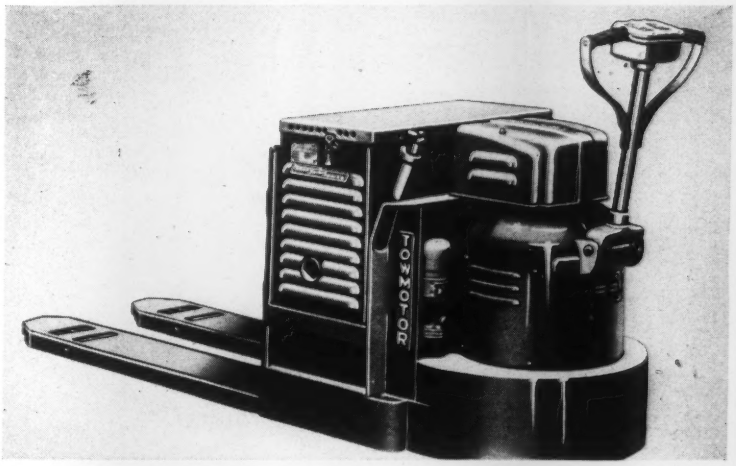
By float control, a working level of tap water is maintained automatically in the sump. A conveniently located drain valve is provided for periodically flushing the sump to remove residual line dirt and mineral concentration.

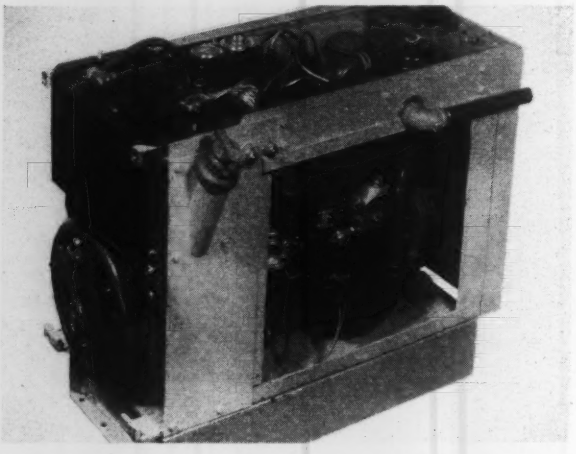
To prevent noise and vibration, the entire condensing unit is suspended on rubber vibration isolation mounts. Driven direct by a capacitor start high-torque motor, the compressor is hermetically sealed and gas cooled. A circular aircooled finned-coil condenser houses the compressor unit.

Built by York Corp., the automatic ice flake maker is said to be the smallest of commercial types yet developed. It occupies a space 25 inches square by 33 inches high and will produce up to 300 lb of ice per day. Exterior casing of the machine is Bonderized and finished in baked Hammerloid gray enamel.

Pallet Truck Generates Own Electric Power

COMBINING the flexibility of an electric drive with the universal availability of gasoline-engine power enables round-the-clock operation of the 2-ton capacity Model W pallet truck, right, built by Towmotor Corp. Occupying the same space as an equivalent storage battery pack, the compact unit eliminates the usual time out required for charging service. The 600-lb power plant, next page, built by the Ready-Power Co., consists mainly of a four-cylinder Hercules engine and a 12-v, 208-amp four-pole generator having its armature mounted integrally with the engine crankshaft. Rubber vibration iso-





lation mounts support the unit on a steel subframe.

Built-in automatic governor control maintains correct engine speed for full voltage under load, and idling speed when not under load. For safety reasons, the fuel tank is built into the base of the housing away from the high-temperature zone, and is equipped with a Protectoseal filler cap.

A key-type ignition switch and starter button are located conveniently on the operator side of the power-unit compartment. Pushbutton stations housed in the steering handle of the traction motor assembly make operation of the truck simple and easy in that they provide three steps in speed with "inch" control for maneuvering in close quarters.

Chamfering Machine Cycles Automatically

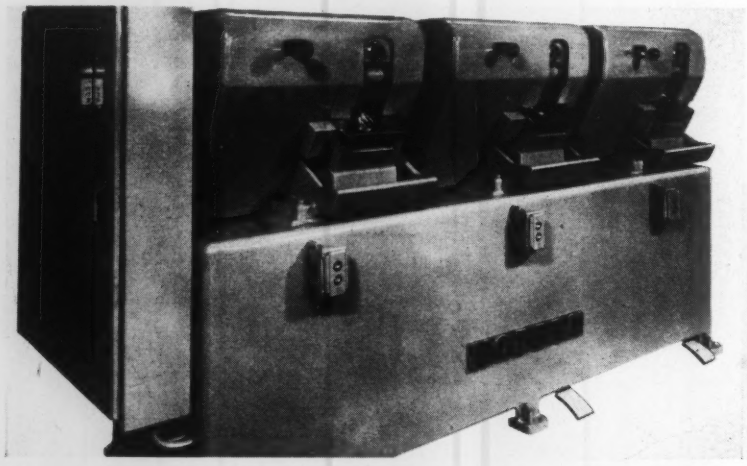
SIMULTANEOUS chamfering of sharp edges at both ends of hypoid pinion teeth is performed automatically by the 3-station machine, below, which is entirely electromechanical in operation. Sketch below, right, shows the location of chamfers produced on a typical pinion in one operation. Dovetail-mounted form cutting tools that require minimum resharpening time are used, and no coolant service is necessary for efficient operation.

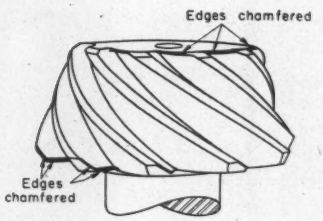
The work holding spindles are set at a convenient angle and height for loading, and safety plates are provided at each station to prevent inadvertent loading of an oversize pinion. Until the workpiece clears the plate and is firmly seated in the spindle, the tools cannot be set in operation. Angular positioning of the work at the start of the cycle is automatic and manual clamping is unnecessary. When a station is loaded properly, operation of a shift lever in the head starts the chamfering cycle. Built-in chutes dispose of the metal chips.

Between cutting operations, the work spindle is indexed by a Ferguson Roller-Gear unit. On completion of the chamfering cycle, a light above the spindle indicates that the station is ready for reloading. To remove the pinion, the shift lever is first disengaged, then operation of a pedal ejects the work from the spindle.

All parts subject to wear are hardened and ground. Antifriction bearings are used throughout except on rocker arms, which have special Ampco bronze bearings because of high compressive loads. Lubrication of change gears, bearings, clutch parts, etc., is provided from a central system to simplify servicing and avoid haphazard lubrication.

The new Burr-Master, as it is known, is also made in single and two-station units. To minimize weight and floor space requirements, welded steel construction and alloy castings have been employed, resulting in compact construction of the three designs. Power requirement is 1-hp per station at a production rate of 300 pieces per hour per station. Modern Industrial Engineering Co., builders of these machines, have applied for patents covering the advanced features represented.





Engineering Cost Analysis

A systematic approach to lower production costs through better design-manufacturing producibility co-ordination

By Richard H. Luders *Production Design Engineer, Lockheed Aircraft Corp., Burbank, Calif.*

Fig. 1—Production design engineer, designer, and cost analyst discuss a design and its correlated manufacturing methods

MANUFACTURING costs of aircraft, like most machines, depend largely upon design configuration. If the design of details, assemblies and installations at their inception is guided with experienced knowledge both of functional requirements and of manufacturing producibility, costs can be directed and controlled so as to result in maximum production economy. To attain this end, however, thorough cost analysis throughout all phases of design, prior to release of drawings for manufacture, is required. By this means, actual facts and figures on production costs involved can be ascertained to provide the basis for final decisions on design configuration.

Cost analysis, as developed within the engineering branch of the Lockheed Aircraft Corp., is primarily a complete evaluation of all the factors contributing to the cost of producing an aircraft part, assembly or installation as a production item. The manufacturing evaluation is a detailed operational breakdown of the production methods and processes. The tooling evaluation is an estimate of the manhours of construction to build the project tools required for fabricating and/or assembling the type of part designed in the quantities contracted. Material costs are a direct application based on size and type of material. Evaluation of engineering design time and manufacturing planning time is actually an estimate of the required designing and planning manhours as well as the apportionment of the time incurred in the control and release systems.

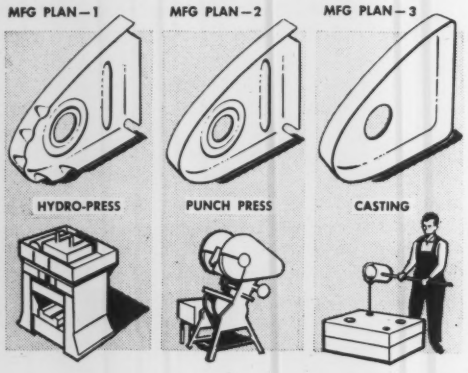
Second consideration is that the engineering cost analysis, as it is known, is usually studied and evaluated on a comparative basis, *Fig.* 1. The different means of manufacture applicable to the design studied are compared to each other costwise, and any manufacturing operation comparable between the methods studied is eliminated in the final analyses. Thus,

when the comparative designs and manufacturing plans have been evaluated, the summarized engineering cost analysis shows the differences in cost. This difference represents the savings possible through good design and its correlated means of manufacture, or conversely, it serves to prevent needless expense in engineering design and manufacturing methods.

Developing Alternate Designs: It must be made clear that the engineering cost analysis is most effective in controlling production costs when evaluated *prior* to the release of new engineering designs to the manufacturing departments. The production engineering department of Lockheed, through its organization—in part—of production design engineers and cost analysts, works in conjunction with the project design departments for the purpose of releasing new designs to the shop in accordance with the most economical consideration. Together, the production design engineer and the designer discuss and predetermine, at the design board, the new design and its variable means of manufacture. Usually two to three plans for producing the details or assemblies are formulated and agreed upon, and together with the corresponding design layouts are turned over to the cost analyst for study and evaluation.

In processing the engineering cost analysis, the first step, as previously explained, is the discussion between the production design engineer and the project designer concerning the design and its possible means of manufacture. Illustrated in *Fig. 2* are leading edge rib designs which could well be produced by three different manufacturing plans. The problem now is to determine which of the selected plans provides the least expenditure of money and manhours of labor for the quantities to be produced. Is manufacturing *Plan* 1, the hydropress forming, the most economical with its simple tooling requirements of a layout and form block template, a router block and form block, all relatively inexpensive; or is manufacturing *Plan* 2, the punch press blank-and-form process, more practical with its high production capacities, but expensive steel dies; or is it possible that manufacturing *Plan* 3, a one-piece casting, most economical and practical for the detail being considered? The settling of these questions can only be done through an analysis which considers the quantity of production parts involved, the materials required, the manhours of production and tooling labor expended and the apportionment of engineering and manufacturing planning charges. Thus, the production design engineer refers the design and proposed manufacturing plans under question to the engineering cost analyst, for comparative evaluation.

Fig. 2—Leading edge rib in three design variations for different methods of manufacture



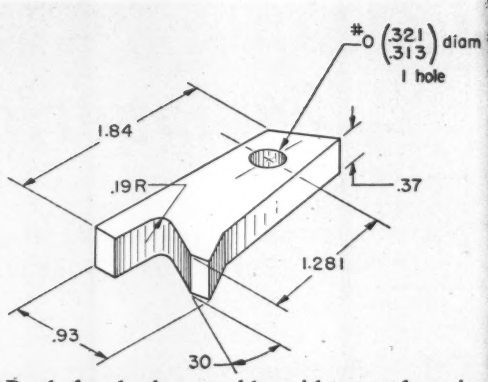


Fig. 3—Pawl for latch assembly with manufacturing processes estimating sheet for outlining preliminary fa

Cost Analysis Procedure: Analysis starts with the known factors—the submitted designs, the proposed manufacturing plans and their requisites. Each plan is separately studied and broken down into its operational elements by the cost analyst. Operations are outlined in sequence on the Manufacturing Operations and Processes Estimating Sheet, as illustrated in *Fig.* 3, showing the breakdown for a latch pawl. Aside from the necessary details filled in the description block, the main consideration is the sequence listing of the fabrication, assembly, installation operations, and processes in the operation and processes block provided.

Operations and processes are outlined in full for each type of manufacturing plan and comparable operations between the plans considered are omitted. The tooling column lists specified tooling (form blocks, jigs, dies, etc.) by code, the estimated manhours to build the tools, and the resultant costs. The setup column is figured in decimal and whole manhours of time required to prepare and start the job for each operation performed. The unit analysis column is divided between manhours of machine run time, part and machine handling time, the total of the two time elements per operation. The specifications and size requirements of the raw material per part are entered in the lower left-hand corner of the form.

In summarizing the total unit cost per part, the material cost is estimated direct on a "per part" basis.

CKHEED AIRCRAFT CORPORATION
RM NO. 3783B-1

REPORT NO.: A-104
DATE: November, 1951

PRODUCTION ENGINEERING - COST ANALYSIS

MANUFACTURING OPERATIONS & PROCESSES ESTIMATING SHEET

Part
sem. Name: Pawl - Latch Assembly — Assem. No.: Design "D" — Model: FB701X
ft. Per Contract: 400 — Acft. Per Lot Release (Aver.): 35
rts/Acft: 12 — Parts/Lot Release: 420 — Parts/Contract: 4800
quested By: J. Doe - Prod. Design Engineer — Cost Analyst: R. H. Luders
udy: #2 - Forged Unit - Machined — Labor Charge: (Prod.) $ 4.58 /Man-Hr. (TLG.) $ 4.95 /Man-Hr. — Page 1 of 1

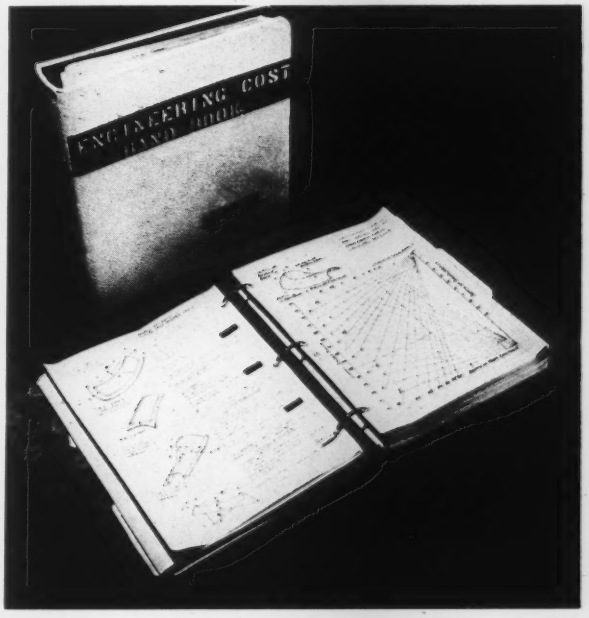
OPERATIONS & PROCESSES	TOOLING CODE	TOOLING M/HRS.	TOOLING COST	SET UP M/HRS./LOT	UNIT ANALYSIS MACHINE M/HRS.	UNIT ANALYSIS HANDLING M/HRS.	UNIT ANALYSIS TOTAL M/HRS.
orging Die Quotation			412.00				
0 - Drill - "O" Hole (.316) - One Place	11C	7.0	34.65	0.5000	0.0100	0.0080	0.0180
0 - Burr - Drilled Hole				0.0600	0.0020		0.0020
0 - Stack Mill (12 Pcs.) - Formed .19R End Rough & Finish Cut (Spec. Cutter)	19G		75.00	1.5000	0.0550	0.0080	0.0530
0 - Stack Mill (12 Pcs.) - Formed Side				1.5000	0.0200	0.0080	0.0300
0 - Mill - Angular End of Part				1.2500	0.0200	0.0060	0.0260
0 - Burr Edges - Wire Brush				0.0600	0.0050		0.0050
0 - Identify - Machine Stamp				0.1000	0.0010		0.0010
OTE: Finishing Operations Comparable Between Studies Made							
				4.970x1.24			.135 x 1.24
(Department Realization Factor 1.24) — TOTAL TIME		7.0		6.1628			0.1674
ATERIAL REQUIREMENTS — SUMMARY COSTS:		$ 521.65		$ 28.23			$ 0.766
Forged Unit - 8630 Steel							

UNIT COST: $ 0.380 MATERIAL + $ 0.109 TOOLING + $ 0.067 SET UP + $ 0.766 OPERATION = $ 1.322 TOTAL

Tooling cost is a factor of total manhours of design and construction multiplied by the adjusted hourly tooling rate (hourly labor rate plus an applied apportionment of overhead and administrative charges), plus cost of tool materials used. This total cost is amortized over the number of parts per airplanes per contract for determining the unit cost. If, for example, there were 5 parts per airplane and contract for 100 airplanes, the amortized share of tooling cost which each part would bear would be the total tooling cost divided by 500.

Setup cost is the total manhours involved for all of the operations performed multiplied by the adjusted hourly production labor charge. The total setup cost is amortized over the quantity of parts per average lot release for determining the unit cost. Illustrating this, using the previous example, 100 airplanes ordered would be released to the production shops (fabrication, assembly and installation lines) in average lot quantities of 15 airplanes per schedule period. With 5 of the same parts used, the average lot release would be 75 parts, and the unit setup cost would be the total divided by 75. Operation unit cost is the direct total of the whole and/or decimal manhours per total operations multiplied by the adjusted hour-

Fig. 4—Cost Handbook contains simplified graphic representations of time standards established for manufacturing operations



ly production labor rate. The sum of the unit costs are totaled giving the cost of manufacturing the part per the quantities involved.

The engineering cost analysis, for thoroughness of manufacturing plan, for accuracy of estimated manhours of labor, and for completeness of cost figures, relies on the experience and ability of the cost analyst and the analysis data. It is, therefore, most important that the analysis data, *Fig.* 3, be a factual collection and compilation of business practices and operations which specifically apply to the organization for which the cost studies are being made.

The most important source of analysis data at Lockheed is the Engineering Cost Handbook, *Fig.* 4. Its graphic and charted representation of standard manhours necessary to perform any of the countless operations of fabrication, assembly or installation, entailed in the manufacture of aircraft, has been developed from the industrial engineering departments time standards. Through numerous and repetitive time studies of operations performed, the time standards division has produced standard formulas and charted time values that apply to the type and quality of work performed at Lockheed. With the factors of operator fatigue, time allowance for personal needs, possible breakdown of tooling and machines during the run, speed rating, etc., all provided for in the final applied time values, the figures together with shop realization factors become factual guides for cost analyses.

The Engineering Cost Handbook provides a quick and easy means, through its simplified manhour graphs, of analyzing and applying the proper time figures to the sequence of all types of manufacturing operations performed per part. Raw material costs of stock on hand are obtained, in general, from averaged inventory price listings. When the costs of new or special materials are needed, quotations are requested from the material planning department or the purchasing department. Analysis data on tool-

LOCKHEED AIRCRAFT CORPORATION
FORM NO. 6377

REPORT NO.: A-104
DATE: November, 1951

COMPARATIVE COST ANALYSIS - PRODUCTION ENGINEERING

- ENGINEERING DESIGN -

DWG. NO. MODEL: Design "D" FB701X

PART DESCRIPTION: PAWL - LATCH ASSEMBLY

REQUISITES:
PARTS PER AIRPLANE 12
" " LOT RELEASE 420
" " CONTRACT 4800

AIRPLANES PER CONTRACT 400
" LOT RELEASE 35

- PRODUCTION ENGINEERING ANALYSIS -

DESIGN STUDY:
#1 Bar Stock Machined
#2 Forged Unit Machined
#3 Investment Casting

REQUESTED BY: John Doe

PRODUCTION & ENGINEERING EVALUATION

COST FACTOR	DESIGN: #1		DESIGN: #2		DESIGN: #3		DESIGN:	
	TOTAL COST	UNIT COST	TOTAL COST	UNIT COST	TOTAL COST	UNIT COST	TOTAL COST	UNIT COST
RAW MATERIAL	$	$ 0.06	$	$ 0.77	$	$ 0.10	$	$
LABOR - RUN TIME	34.93	2.03	28.23	0.07	2.84	0.01		
LABOR - SET UP	124.50	0.09	521.65	0.11	409.65	0.08		
DETAIL TOOLING	10.50	0.01	10.50	0.01	7.50	0.01		
PLANNING RELEASE	75.00	0.02	75.00	0.02	75.00	0.02		
ENGINEERING "				0.38		1.75		
PURCHASE QUOTATION								
O.P. QUOTATION								
COMPARATIVE COST - TOTAL	$	$ 2.22	$	$ 1.36	$	$ 1.97	$	$

CONCLUSION: a) The machined forging is the most economical manufacturing plan of the designs studied and for the quantities involved.
b) The savings in cost between Plan #1 and Plan #2 amounts to $4,128.00 per contract.
c) A special contour milling cutter was considered in Plans #1, and #2 for form cutting the .19R and adjacent lands.
d) Delivery on forging -- 4 months.

BREAK EVEN POINT New Designs.

COST ANALYST: R. L. Ludens

Fig. 5—Comparative cost analysis form for the latch pawl of *Fig.* 3

ing and manufacturing planning is composed of construction figures derived from past records. With new developments in tooling and tooling materials, the analyst maintains contact with the shop for realistic figures. The purchasing and outside production departments are most important in securing price quotations based on quantities from vendors on such items as castings, extrusions, forgings, special materials and parts—as well as subcontract bids. Also at hand are reports, charts, graphs, etc., issued by the cost accounting, industrial engineering, purchasing, manufacturing and tooling departments all of which either directly quote costs and prices or contain information influencing costs.

The engineering cost analysis is summarized and concluded by entering collectively the unit costs, from the estimating sheets, *Fig.* 5. The engineering design section pertains to the part or assembly description and its production and contract requirements. A section on production engineering analysis provides space for a numerical listing and brief description of each of the manufacturing plans studied. The production and engineering evaluation section is for the estimated unit and total cost figures from each of the estimating sheets and are entered according to the cost factor column. It is to be noted that four of the cost factors, namely, labor setup, detail tooling, planning release, and engineering release charges, are entered both as total and unit charges. Depending on need or use of the figures, this can be optional; however, these are generally shown as totals since they have a direct relationship in their entirety to either lot release quantities or total contract quantities of parts or aircraft delivered.

When unit cost factors are totaled for each of the manufacturing plans studied and are viewed with respect to each other, the answer as to which is the least expensive or most economical means of manufacture is apparent. However, it is not conclusive until all facts are presented and considered. The conclusion block serves this purpose in presenting statements commenting on: (1) The more, or most, economical plan of manufacture of the plans studied; (2) savings possible, per contract, from the cost differences indicated, and also weight differences of the considered designs; (3) noting for any particular manufacturing method involved, of special tooling or materials required, etc.; and (4) any pertinent information about vendor quotations, delivery dates on purchased items, quantity price breaks, etc. Final use of the completed comparative cost analysis is as a guide for the production design engineer and designer in reaching a decision and releasing the design as a producible and economical unit.

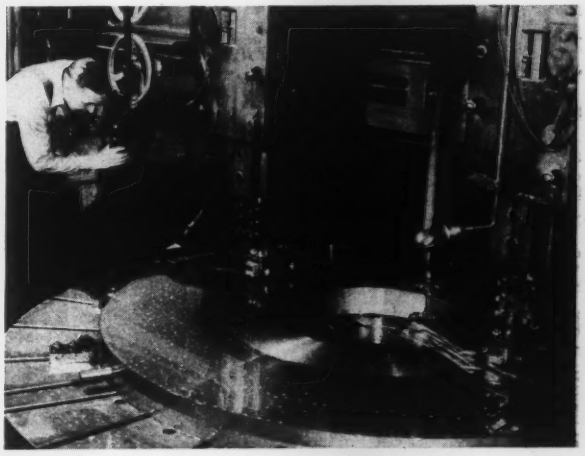
Prerequisites for Cost Analysis: Reliability of the engineering cost analysis, other than its statistical data and estimating methods, depends on the cost analyst and his background of training and experience. The combined experience of engineering and manufacturing planning is most necessary. The ability to understand the design, to visualize it as a finished product, to plan step by step the sequence of manufacturing operations for each of the methods considered, to plan and evaluate the production tooling required commensurate with the quantity of airplanes or parts to be produced, to understand the materials and their fabrication qualities, and to be familiar with the shop equipment and machinery available within or outside of the company is essential. A background of general and cost accounting is most appropriate for organized thinking and derivation of costs. And certainly important is training and experience in time and motion study for the interpretation of time standards and their practical application.

Value of the engineering cost analysis is in its use. As a bona fide presentation of facts and figures it can have a far reaching effect in securing economical design and product manufacture. The comparative cost analysis reveals the differences in cost of engineering and manufacturing for the studies evaluated, and does not attempt to portray the total manufacturing costs of any of the plans studied. The reasons are for simplicity and ease of estimating and to arrive as quickly as possible at the core of the analysis—the savings.

Approach to engineering cost analysis must be with respect to the application of general semantics, i.e., the recognizing and securing of facts and not opinions about design and the manufacturing plans. There can be no "crystal ball" gazing involved, but rather a statistical and practical evaluation. Added to this must be a reliable and accurate source of cost data and its sound interpretation and application to the problem by competent anlysts.

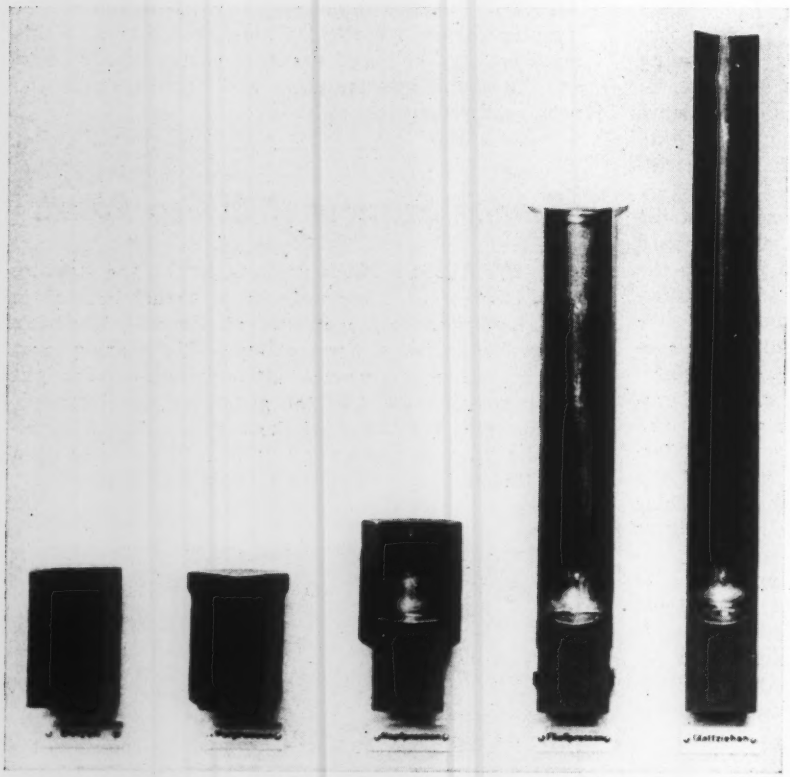
Bearing Supports 2 Million Pounds

A MIRROR-SMOOTH finish is put on the rotating element of a hydrogenerator thrust bearing in this final grinding operation at General Electric's Large Motor and Generator Dept. The bearing must support a load of almost 2 million pounds—the weight of all rotating parts of the generator and hydraulic turbine plus the thrust of the turbine. The fine polished surface is necessary so that a film of oil only a few thousandths of an inch thick will be formed.



Cost Reduction Through Cold Extrusion

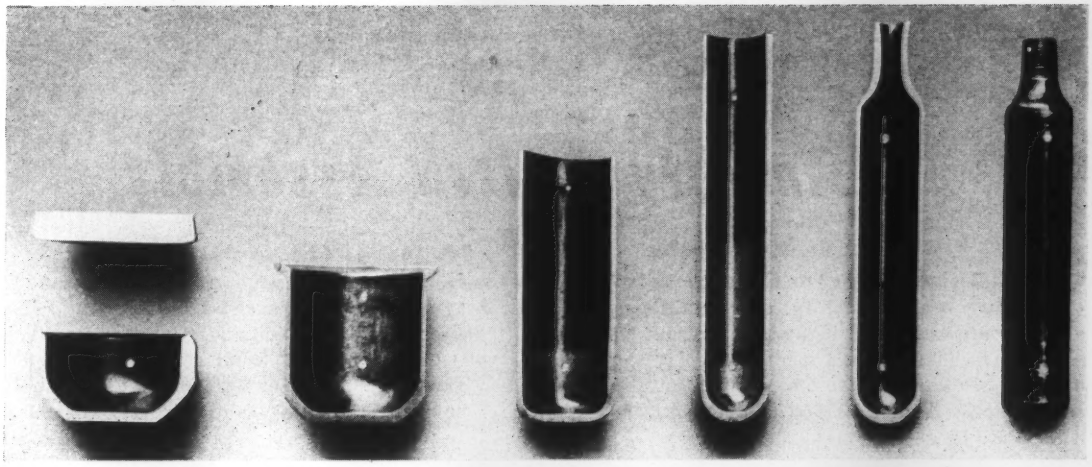
Continued development in this relatively new field reveals numerous economic design opportunities



Above—German shock absorber housing produced from hot-rolled bar stock. Operations are: (1) Coining, (2) combination backward and forward extrusion and, (3) final drawing

COLD extrusion of steel parts, only recently brought into the realm of commercial production, offers the designer many of the opportunities formerly only possible with nonferrous metals with the impact or Hooker extrusion processes. Made possible by means of phosphate coatings and special drawing compounds, cold extrusion was first practiced successfully by German industry using Parker Rustproof Co. Bonderite coatings. The astonishing results observed in Germany led to further development following World War II and, today, many of

Right—A 13-pound, 2.5-inch thick blank extruded to form a cupped gear blank 6.75 inches long. Blanking and coining is followed by a single extrusion operation to form a close-tolerance gear of high physical properties

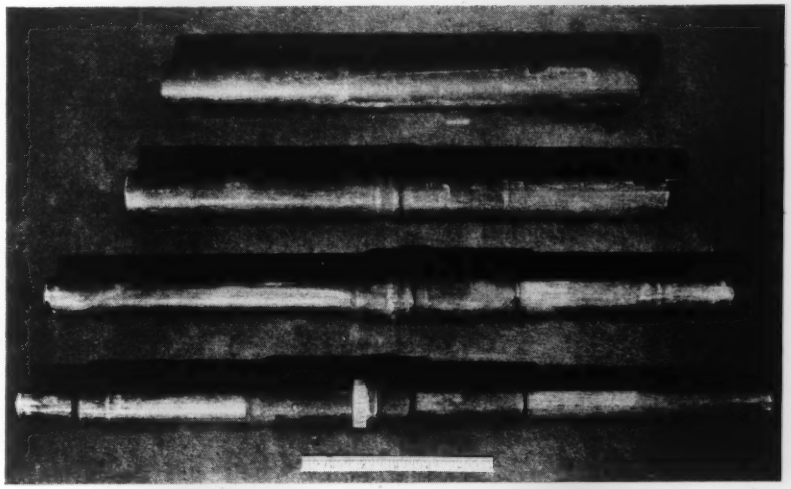


Above—Cold-extruded flask for carbon dioxide. First step is a backward extrusion, second a forward extrusion, next are two draws and a necking operation and finally, threading

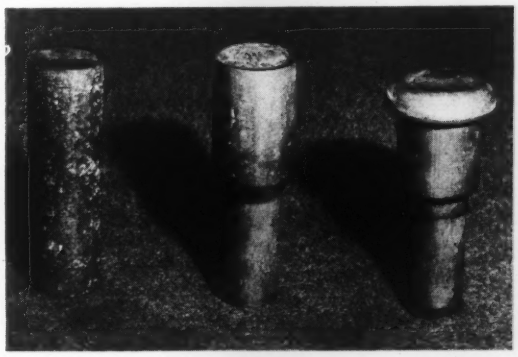
the seeming obstacles of die and pressure limitations have been fast disappearing to the end that this process now is reaching the point where designers must consider it along with all the others in their preliminary studies.

The accompanying illustrations typify parts produced by cold extrusion methods using Bonderite coatings and indicate some of the unusual design possibilities. The dimensional accuracy achieved in cold extruding along with the surface refinement eliminates need for machining in most cases. Improvement in physical properties makes possible use of lower carbon steels as well as considerable savings in machine time and man hours.

Below—Automotive transmission drive shaft. Cold extrusion from low-carbon steel in lieu of machining from special alloy bar resulted in substantial savings



Stud bolt-blanks cold extruded as the first operation and upset to form the final contours



Heavy cup cold formed from a section sawed from hot-rolled bar stock. Metal savings over previous method of drawing from rolled plate amounted to approximately 30 per cent

PLASTICS

Simplify Switch Assembly

THE designer of switches must often display quite a bit of ingenuity to maintain simplicity in manufacture and assembly, without sacrificing adequate mechanical and electrical operating characteristics. In each of the two applications shown the special properties of a particular plastic have been utilized for these purposes.

A switch assembly manufactured by a leading clock manufacturer is now fastened with nylon rivets, *Fig.* 1. The solid round-head rivets, each about ¾-inch long, are cut on automatic screw machines from 3/16-inch diameter nylon rod. Switch contact arms are supported between small stamped phenolic wafers, and the assembly is fastened with Tinnerman nuts on the two rivets. Thus, instead of spinning nuts onto the rivets, the nuts can be driven on, the resiliency of the compressed nylon holding the nuts firmly. The application has received Underwriters' Laboratories approval for 110 volts ac.

In the second application—a solenoid switch—a glass-fiber polyester laminate is used to obtain a higher electrical rating than formerly possible. Originally restricted to ac circuits, the redesigned switch shown in *Fig.* 2 is adapted for use on dc circuits. The glass-plastic material was first utilized by the Soreng Mfg. Corp. for the contact head, primarily to prevent warping and shrinking at elevated temperatures, which cause poor contact. Later the manufacturer made the same substitution in the terminal head, which serves as mechanical support as well as electrical insulation for the current-carrying elements of the redesigned solenoid switch.

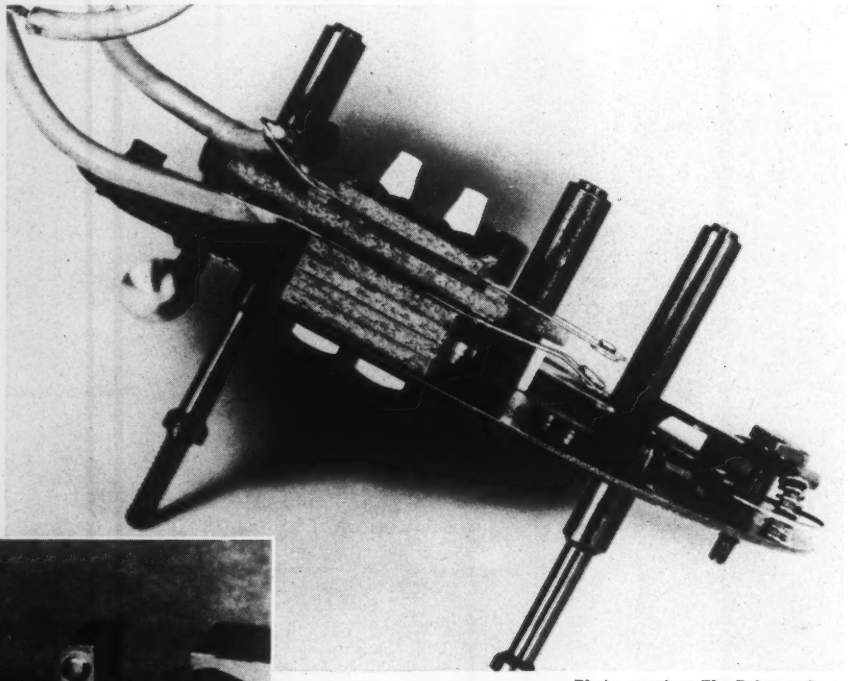
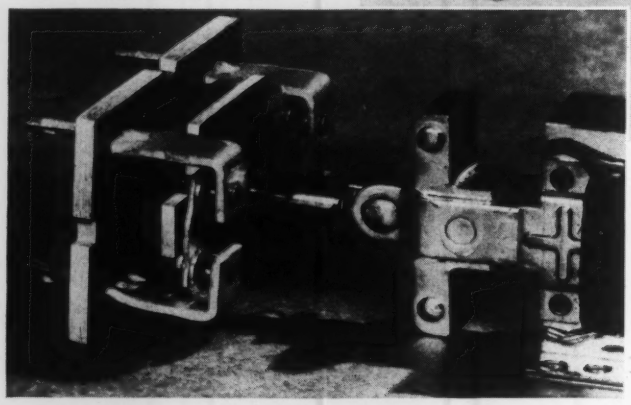


Fig. 1—Right—Machined nylon rivets fasten the switch-contact and insulation-wafer assembly in this clock switch

Photo, courtesy The Glastic Corp.



Photo, courtesy The Polymer Corp.

Fig. 2—Left—Redesigned to obtain a higher electrical rating, this solenoid switch utilizes a glass-fiber reinforced polyester laminate for the contact and terminal heads

Helical Spring Design

Simplified method groups variables for convenient chart solution with circular and rectangular section wire

By N. Sag
Head, Machine Design and Drawing Dept.
Melbourne Technical College
Melbourne, Australia

HELICAL springs of circular or rectangular-section wire are frequently used machine components. Many charts exist for the design of such springs. However, because of the many variables involved, most of these methods are based on trial and error.

If the variables involved are formed into dimensionless groups, it is possible to express the relationships for any one spring by mere numbers. If this is done, trial and error can be avoided. Charts based on such dimensionless grouping for the design of helical springs are presented in this article.

For circular-section wire the maximum shear stress and the deflection per coil in close-coiled helical springs, when subjected to a load P, can be expressed as

$$s = \frac{8PKD}{\pi d^3} = \frac{8PKc^3}{\pi D^2} \quad (1)$$

$$\delta = \frac{8PD^3}{Gd^4} = \frac{8Pc^4}{GD} \quad (2)$$

Equations 1 and 2 can be written in the following dimensionless forms

$$\frac{\pi s D^2}{8P} = Kc^3 = A \quad (3)$$

$$\frac{GD\delta}{8P} = c^4 = B \quad (4)$$

The dimensionless quantities A and B are functions of the spring index c only and are plotted in *Fig.* 1.

For rectangular-section wire similar expressions can be obtained. However, an additional dimensionless variable k, defining the shape of the rectangle, enters the equations.

The maximum shear stress and the deflection per coil[1, 2] under load P can be written as follows:

[1] References are tabulated at end of article.

Nomenclature

A = Chart factor for stress of circular wire spring
A' = Chart factor for stress of rectangular wire spring
B = Chart factor for deflection of circular wire spring
B' = Chart factor for deflection of rectangular wire spring
$c = D/d$ = Spring index
D = Mean diameter of coil, inches
d = Diameter of circular wire, or width of rectangular wire measured radially, inches
G = Modulus of rigidity, psi
h = Height of rectangular wire, inches
K = Stress correction (Wahl) factor for curvature
$k = h/d$ = Rectangular shape factor
N = Number of active coils
P = Spring load, lb
s = Shear stress, psi
y = Total deflection, inches
α = Dimensionless stress factor
β = Dimensionless deflection factor
δ = Deflection per coil, inches

$$s = \frac{PD\alpha}{2dh\sqrt{dh}} = \frac{\alpha c^3}{2k^{3/2}} \frac{P}{D^2} \quad (5)$$

$$\delta = \frac{PD^3\beta}{d^2h^2G} = \frac{\beta c^4}{k^2} \frac{P}{DG} \quad (6)$$

Both α and β are functions of c and k. The dimensionless forms of Equations 5 and 6 are

$$\frac{sD^2}{P} = \frac{\alpha c^3}{2k^{3/2}} = A' \quad (7)$$

$$\frac{GD\delta}{P} = \frac{\beta c^4}{k^2} = B' \quad (8)$$

Values of A' and B' in Equations 7 and 8 for various k values are plotted as functions of c in *Fig.* 2.

Design charts in *Figs.* 1 and 2 can be used by calculating the value of A or A' from known values of permissible maximum shear stress s, maximum load P and the mean diameter of the coil D. Usually D is known from the space dimensions into which the spring must fit. For rectangular wire the shape can be assumed and a suitable $k = h/d$ is chosen. With the knowledge of A or A' the appropriate value of the spring index can be found and in turn the corresponding value of B or B' can be determined from the

Data Sheet

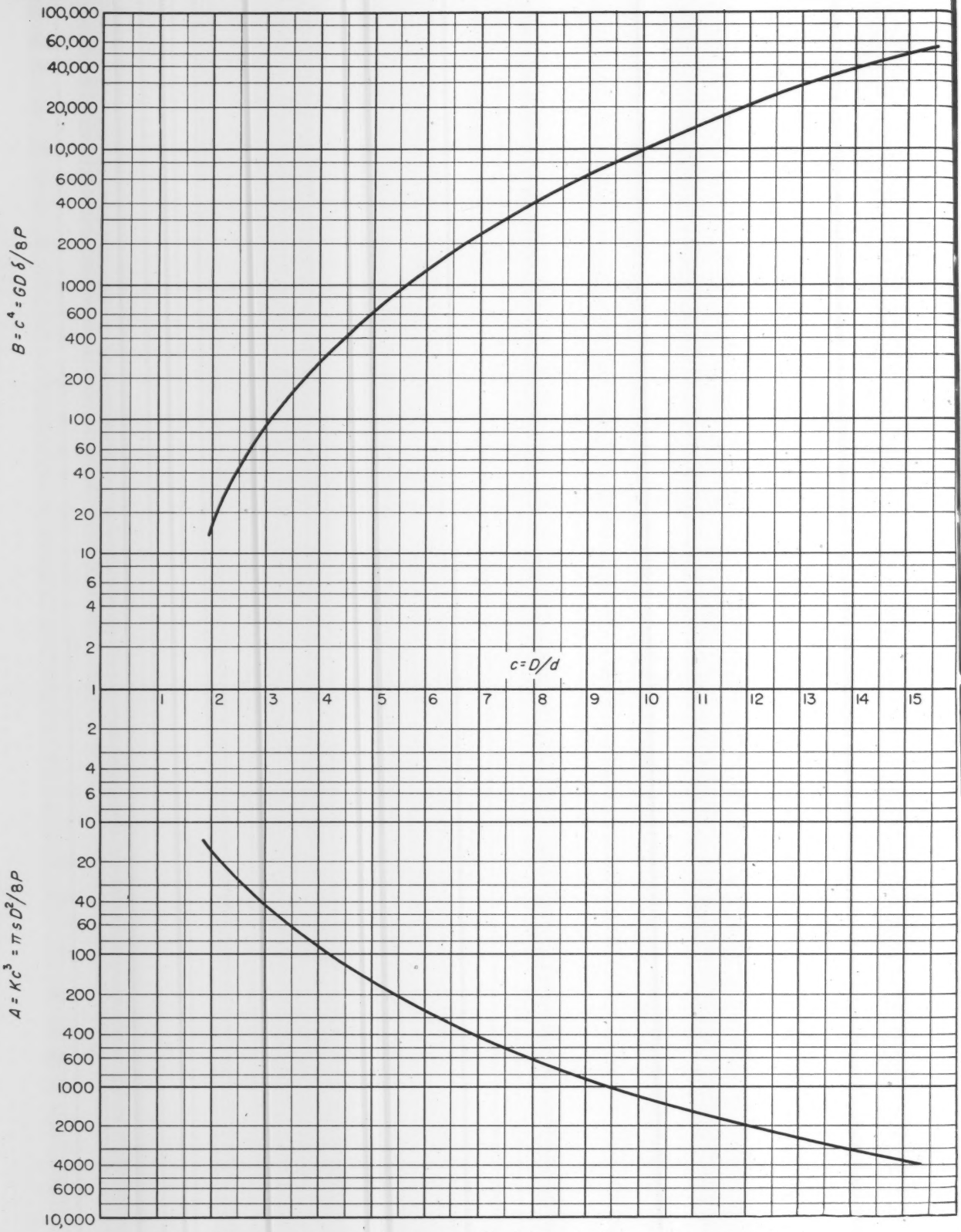


Fig. 1—Chart for determining properties of helical springs of circular-section wire

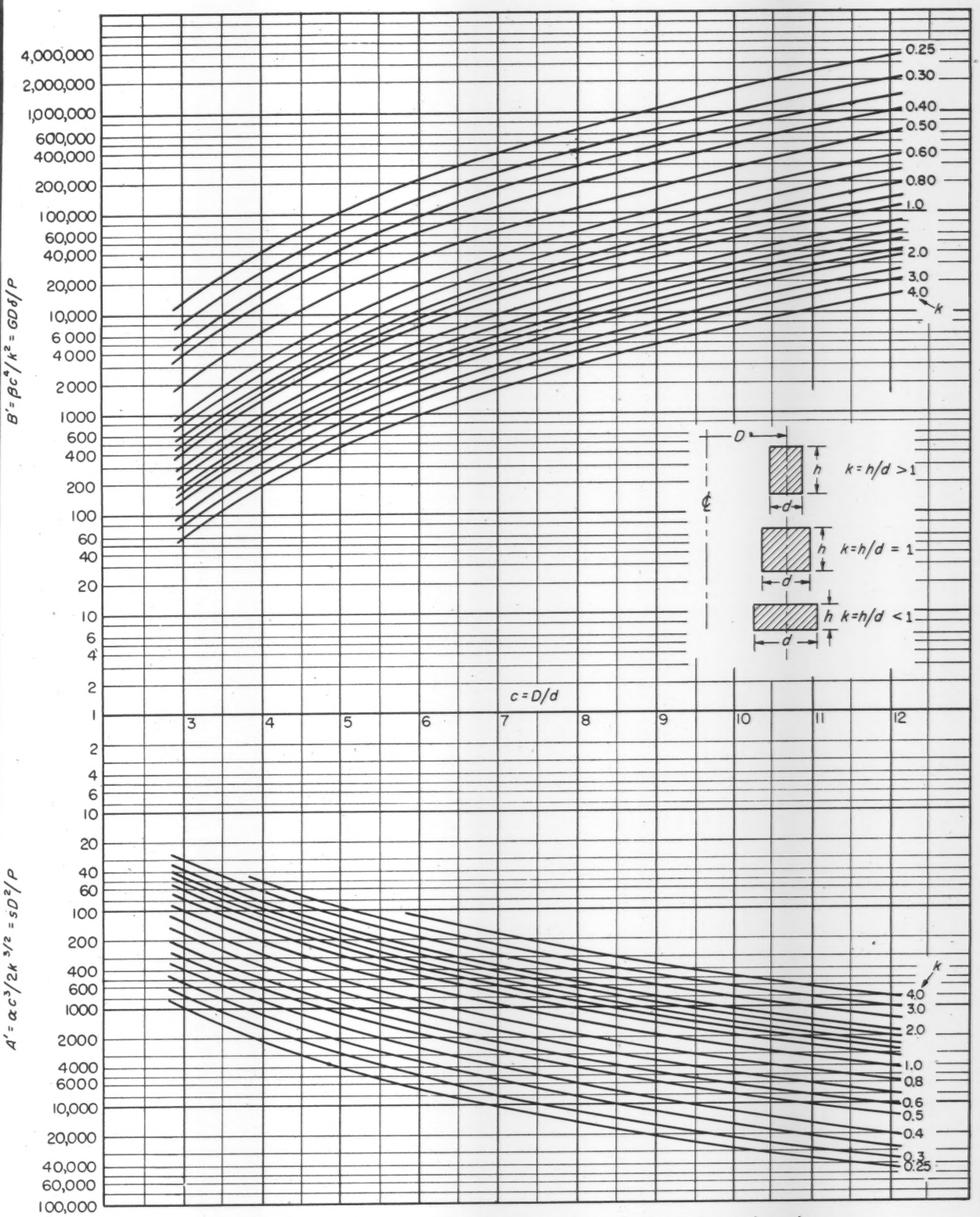


Fig. 2—Chart for determining properties of helical springs of rectangular-section wire

charts. The deflection per coil for a given material can be then calculated from B as follows: For circular section wire

$$\delta = \frac{8PB}{GD} \quad \ldots\ldots (9)$$

For rectangular section wire

$$\delta = \frac{PB'}{GD} \quad \ldots\ldots (10)$$

If the total deflection required under load P is equal to y, the number of active coils is simply

$$N = \frac{y}{\delta} \quad \ldots\ldots (11)$$

Values of the modulus of rigidity G and recommended maximum shear stress s for various materials are listed in TABLES 1 and 2, respectively.

EXAMPLE 1: Design a clutch spring of oil-tempered carbon spring-steel wire to fit over a 3-inch diameter shaft. The load conditions are as follows: 250 lb force is required to keep the clutch engaged and 300 lb is required to disengage it by ½-inch withdrawal of the sliding part of the clutch. A futher ½-inch movement compresses the spring to a solid height.

From the load deflection diagram, *Fig.* 3, the maximum force at solid height P = 350 lb, initial compression required to exert 250 lb force is y_0 = 2.5 inches and the total deflection at solid height is y = 3.5 inches.

Table 1—Modulus of Rigidity

Material	Modulus (psi × 10^{-6})
Carbon steel	11.5
Alloy steel	11.5
Stainless steel, 18/8	11.0
Monel metal	9.5
Beryllium copper	6.5
Phosphor bronze	6.3
Spring brass, 64-72% copper	5.5

Table 2—Recommended Maximum Shear Design Stress*

Material	Shear Stress (psi)	Size
Music wire	100,000	Up to 16 gage
	90,000	Over 16 gage
Oil tempered spring steel	100,000	Up to $\frac{3}{32}$-inch diameter
	90,000	$\frac{3}{32}$ to ⅛-inch diameter
	80,000	Over ⅛-inch diameter and rectangular
Hard-drawn spring steel	90,000	Up to ⅛-inch diameter
	80,000	Over ⅛-inch diameter and rectangular
Stainless steel, 18/8 hard-drawn	85,000	Up to ⅛-inch diameter
	75,000	Over ⅛-inch diameter and rectangular
Beryllium copper, 98% copper, 2% beryllium, cold-rolled or drawn	65,000	All usual sizes
Phosphor bronze	50,000	All usual sizes
Monel metal	50,000	All usual sizes
Spring brass, 64-72% copper	40,000	All usual sizes

* For static load, noncorrosive atmosphere and normal temperature range.

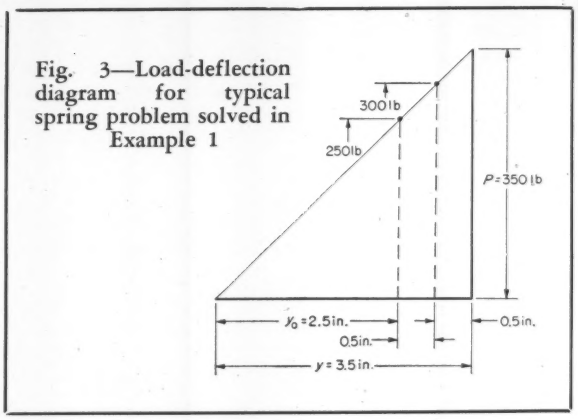


Fig. 3—Load-deflection diagram for typical spring problem solved in Example 1

Estimated mean diameter of coil D = 3.5 inches. The recommended maximum permissible design stress from TABLE 2 is s = 80,000 psi. Thus from Equation 3,

$$A = \frac{\pi(80{,}000)(3.5^2)}{8(350)} = 1100$$

From *Fig.* 1 then c = 9.8 and $d = D/c$ = 0.36. With 0.375 diameter wire, the corrected spring index is $c' = 3.5/0.375 = 9.35$ and the corresponding value of B from *Fig.* 1 is 7500.

The deflection per coil for $G = 11.5 \times 10^6$ (TABLE 1) is, from Equation 9,

$$\delta = \frac{8(350)(7500)}{11.5(10^6)(3.5)} = 0.522 \text{ inches}$$

and from Equation 11 the number of active coils required is

$$N = \frac{3.5}{0.522} = 6.7$$

Another example illustrates the use of *Fig.* 2 for rectangular section wire.

EXAMPLE 2: The spring of a spring balance is to be rectangular-section wire with a shape factor of k = ½. The maximum force on the spring is P = 100 lb and the material used is hard-drawn spring steel. The mean diameter D = ¾ inch. From Equation 7,

$$A' = \frac{80{,}000(0.75^2)}{100} = 450$$

From *Fig.* 2 for k = ½ and A' = 450, c = 3.6. Then $d = D/c$ = 0.208 inch and $h = 0.5d$ = 0.104 inch. Also from *Fig.* 2 for c = 3.6, B' = 4200. Thus the deflection per coil from Equation 10 is

$$\delta = \frac{100(4200)}{(11.5)(10^6)(0.75)} = 0.0486 \text{ inches}$$

If a graduated scale length of 1 inch is required the number of coils must be

$$N = \frac{1}{0.0486} = 20.6$$

Acknowledgement is due to Roger Churchward for checking the numerical tabulations from which *Figs.* 1 and 2 were constructed.

REFERENCES

1. A. M. Wahl—*Mechanical Springs*, Penton Publishing Co., Cleveland, 1944, Pages 212-220.
2. Liesecke—*VDI Zeitschrift*, Vol. 77, 1933, Pages 425, 892.

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Arma Corporation
Brooklyn, New York

DESIGN ABSTRACTS

Electric Servomechanisms in Design

Basic analysis of closed-loop electric servomechanisms for automatic control of machines

AUTOMATIC control is a modern idea—a natural outgrowth from the root concept, control. Through the years man has developed many wonderful sources of energy which have placed at his disposal the potential to do work far beyond human or animal strength capabilities. To produce useful work from these energy sources, two operations are required. First, energy must be transformed into the proper form to do the required job. Second, this energy must be precisely directed or controlled, both in magnitude and sense, to produce the desired effect.

The order designating the desired effect is normally a weak signal of low energy content. Typical orders might be produced by turning a dial or pushing a button. On the other hand, the process or machine actually doing the work might draw large amounts of energy, perhaps several hundred horsepower. Obviously, a link is needed to connect the low-energy order with the high-energy load. This link is the control system and may be manual, semiautomatic or fully automatic. Regardless of the man or machine elements involved, the control system as a whole or in part must fall into one of two categories:

1. Open-end or open-loop control
2. Closed-loop or feedback control.

Methods of open-loop and closed-loop control are well known. For example, every one knows how an automobile is operated. The driver guides his vehicle along the road by continually observing his position with respect to a reference, such as a white line or the side of

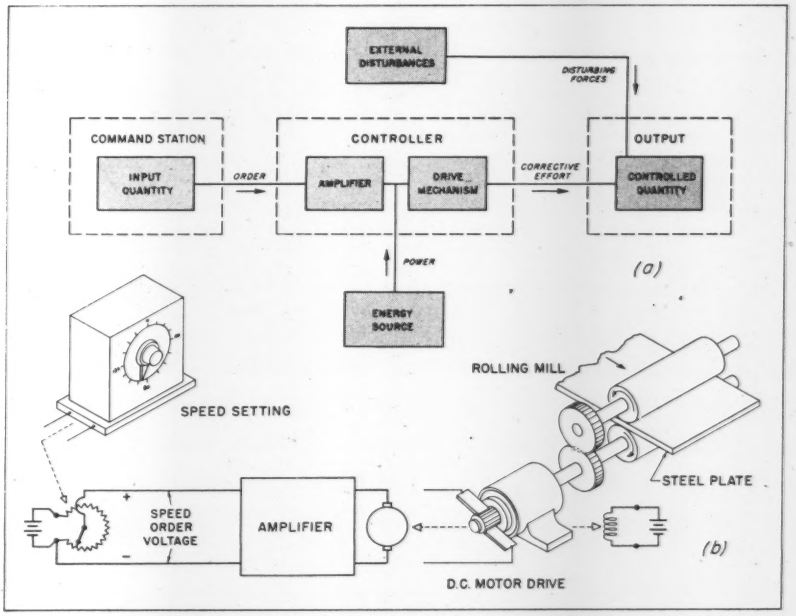


Fig. 1—Open-loop control system shown in block diagram, *a*, is utilitzed to maintain speed of rolls in the manufacture of steel plate, *b*

the road. Should his path deviate from that desired, he merely turns the wheel enough in the proper direction to correct the observed error. This is closed-loop control. The driver continually monitors the actual path of the car against the path desired and applies a proportional corrective order to the vehicle, via the steering wheel, to obtain accurate control of motion. The loop is considered closed because the response of the car is compared with the order of the driver and the difference is applied as a signal to eliminate the observed error.

It is also possible to steer automobiles by the open-loop principle. According to this scheme, the steering wheel is carefully adjusted to put the car on the right path whereupon the driver opens the loop by removing his eyes from the road, possibly to more delectable scenery. Because of changes in the road contour or errors in the overall steering mechanism, such as lost motion in the gearing, the vehicle soon moves off course — possibly to kingdom come.

There are many other examples of open and closed-loop control in life about us. Control engineering as a science has merely adopted the principles, formalized the thinking and developed techniques and equipment for implementing fully automatic control systems.

Open-Loop Control: An open-loop control system is shown in the block diagram in *Fig. 1a*. The objective of this system is to accurately control the output in proportion to an order originating from the command station. The output may be a machine or process while the variable to be actually controlled has been designated as controlled quantity. Controlled quantity might mean the position of a cutting tool, speed of a lathe, elevation of a gun, or temperature of a process. Frequently, the variable under control may in turn influence another quantity which is actually the end result desired. For example, controlling the cooling rate of a metal would in effect govern the crystalline structure.

The command station calls for a change in the output by resetting the input quantity to produce a new order. This might mean resetting a dial or pushing a button, thus initiating a proportionate order signal. The order signal actuates the controller which produces the change by applying a proportional corrective action to the output.

Within the controller there are two basic elements, the amplifier and drive mechanism. The amplifier raises both the volume and power level of the order signal, draining power, as required, from the energy source. A powerful order signal, thus developed, is then applied to the drive mechanism, which actually does the work in altering the controlled quantity. In many systems, external disturbances which are present tend to disturb the controlled quantity setting, causing deviation from the desired response.

A basic property of the open-loop control system is proportionality. Accuracy is entirely dependent on the precision to which all tandem system elements can be calibrated and maintained. In the face of external disturbances — variations of quantities such as line voltage, ambient temperature, pressure and humidity, aging of components, and changes in loading—the problem of precise setting and maintenance of calibration becomes a formidable, expensive and, all too often, impossible job. All of these factors point to the main fault in open-loop control. It is a type of system which has no means for recognizing when it is in error. In fact, even if it could detect errors, it could do nothing about them.

A typical control problems is one such as might occur in a steel factory. For example, in the manufacture of steel plates it is important to be able to maintain precise control on the speed of rolls in the

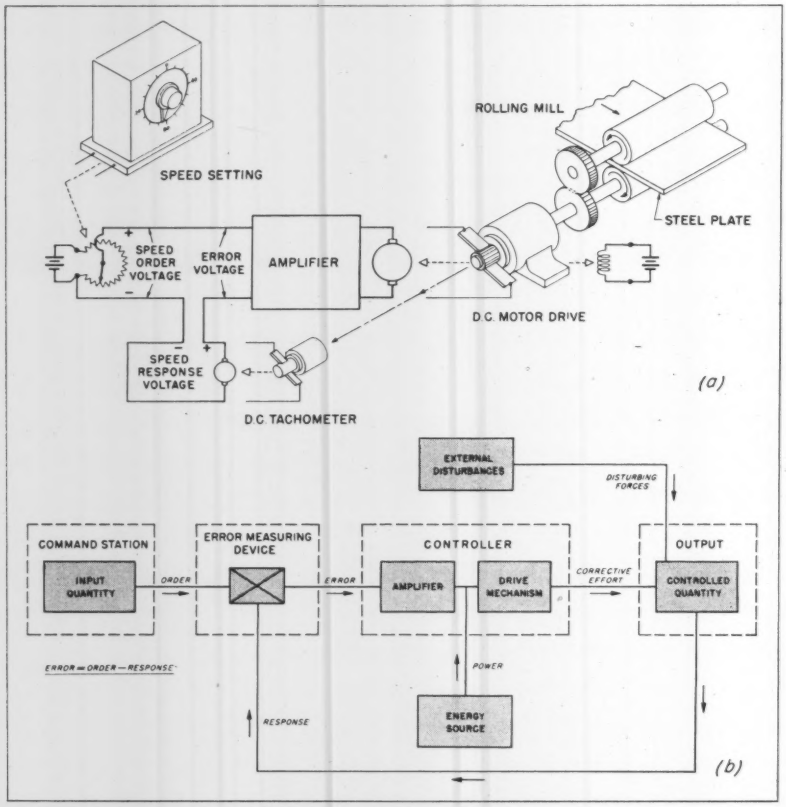


Fig. 2—Automatic control of roll speed, *a*, has been accomplished by adding an error-measuring tachometer to the system in *Fig. 1b* thus providing a closed-loop or servomechanism control system of the general type shown in the block diagram, *b*

rolling mill. The schematic diagram in *Fig.* 1*b* shows a method for speed control by the open-loop principle. Power is furnished to the drive by a separately excited dc motor. Speed at a fixed load is proportional to the applied voltage. A potentiometer, calibrated in terms of speed at the rolling mill, is provided to supply proportional, speed signal voltages. The amplifier gain is linear so that a constant ratio is maintained between its signal input and the voltage input to the motor.

To expect such a system to have an accuracy better than 25 per cent is not realistic. Variation of rolling mill load, line voltage, ambient temperature and aging of the amplifier all contribute very important errors. Compensation means are possible but at best become difficult and expensive while providing only marginal improvement.

Closed-Loop Control: A simple means for improving the control system in *Fig.* 1*b* would be to connect a speed-measuring device to the output with an operator stationed at the speed signal potentiometer to correct any observed errors in speed. However, under these conditions the control is no longer open loop. The operator and tachometer serve to provide a semiautomatic closed-loop system.

To make this system fully automatic and eliminate the operator is quite simple, *Fig.* 2*a*. In this system speed orders are provided as in the open-loop drive. However, there is one additional element, a tachometer. This tachometer is actually a precision generator producing voltages, proportional to speed, which are inserted in series with the speed signal voltages in the input circuit of the amplifier. The two voltages are opposing so that any differences appear at the amplifier input. When the output speed matches the value indicated by the speed signal the two voltages are matched and the resultant input to the amplifier is zero. However, should the speed be less than ordered, the tachometer voltage will decrease and there will be a voltage input to the amplifier. The amplifier reacts instantly to increase the voltage at the motor terminals which results in an increase in motor speed. When correct speed is again attained, the tachometer voltage matches the speed signal and reduces the amplifier input to zero. Increased voltage is no longer applied to the motor and the output shaft runs at normal signal speed.

Accuracy in this system is determined by two factors. The first factor involves the precision of the speed-signal potentiometer and speed-response tachometer. Potentiometers are available to 0.1 per cent accuracy, or better, for fixed settings; tachometers are readily available to 0.2 per cent. Thus, with relatively inexpensive, commercially obtainable equipment, instrument errors in the order of 0.3 per cent maximum might be expected.

The second factor, peculiar to closed-loop control, concerns the voltage always required to supply motor losses and load torques. If the ratio of motor voltage to amplifier input is made very high,

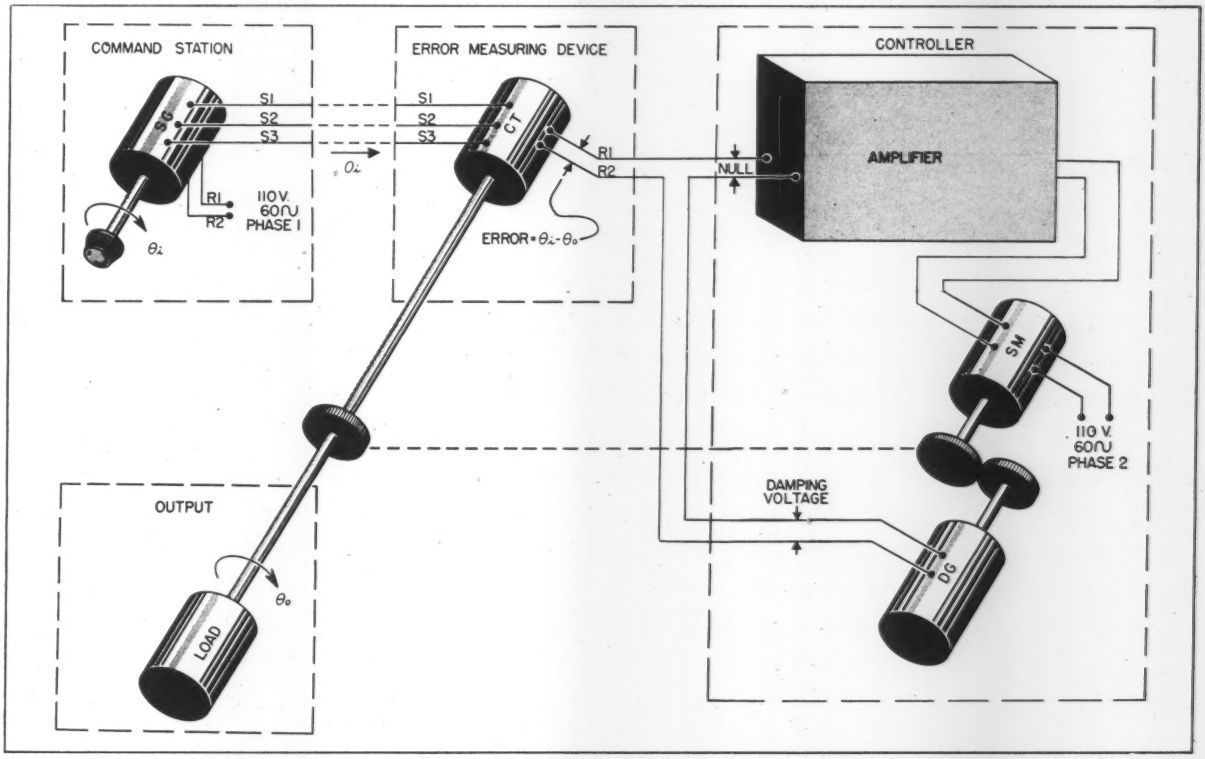


Fig. 3—Simple angle repeater servomechanism positions load to angular heading, θ_o, in accordance with orders transmitted from a remote command station

that is if high amplifier gain is provided, only a small voltage is required at the amplifier input. This voltage is a direct measure of the speed error which may be held to 0.2 per cent.

If the 0.3 per cent error due to calibration is added to 0.2 per cent from closed-loop operation the maximum possible error becomes 0.5 per cent, some 50 times less than in the open-loop system.

To accomplish this improved control accuracy only one element was added, a relatively inexpensive commercially available tachometer. At the same time the calibrated controller was eliminated and replaced by a controller supplying high torques for small changes in speed. A standard motor together with a relatively crude amplifier will do this job cheaply, reliably and automatically.

A generalized block diagram of the closed-loop system is shown in *Fig. 2b.* In this diagram there is only one functional box which does not appear in open-loop control—the error measuring device. This device compares the order with the response and transmits the difference, or error, as an input to the controller. The controller reacts instantly and applies a strong corrective action to the controlled quantity, forcing it in a direction to reduce the error. The controller draws its power from the energy source and will continue to labor as long as its input indicates system error exists.

In this system, the only basic source of error, other than inaccurate calibration of order and response, arises from losses within the controller and the forces required to drive the load. The controller will only deliver power in response to input and the only source of input is system error. This error, however, may be decreased by increasing the controller gain or amplification. The larger the gain the less error required to supply the same corrective action at the controller output.

Unfortunately, the gain cannot be increased indefinitely without soon being affected by the sort of trouble called hunting, oscillation or system instability. When this occurs the controlled quantity hunts about its zero position either continuously, or for a long time before coming to rest. However, by introducing some form of electrical, mechanical or hydraulic damping the system can be brought to rest in a minimum of time, dead beat if necessary.

Since the inception of feedback control, stability with high gain has been a problem. Today this problem is readily handled in many ways. High gain, stable systems are quite commonplace. In fact, even zero error, low-gain systems are readily possible by using some of the more advanced methods available.

The diagram, *Fig. 2b,* is general for any simple closed-loop control system regardless of the type and mixture of component elements involved. It is not uncommon to find electrical, mechanical, hydraulic and chemical elements in a single system. Closed-loop systems are most familiarly referred to as servomechanisms. Literally, servomechanism means slave mechanism, a device conceived to follow commands faithfully.

In the beginning the use of servos was limited to simple remote positioning systems. Today the servo does a multitude of tasks quite ably. It has been recognized that the servo, in addition to muscles, has "brains." The "brains" of a servo stem from three basic properties:

1. Multiple-input variables controlling one dependent variable
2. Automatic and accurate null setting
3. Intelligence smoothing as a low-pass filter.

The first property permits any reasonable number of variables to be injected into the input of the servo. The servo merely drives the single controlled quantity to a value which satisfies the second property so that the sum of all input variables plus controlled quantity is a null, as indicated by zero servo error.

With these two properties, any equation, including implicit types, with a single unknown can be solved. If there are two unknowns, two servos are required. A continuous solution is always obtained and the answer is available physically, for example, as a shaft rotation. This characteristic is important, for physical answers are required in most cases of machine or process control.

The third property of servos, intelligence smoothing, is obtained by adjusting the servo so that it

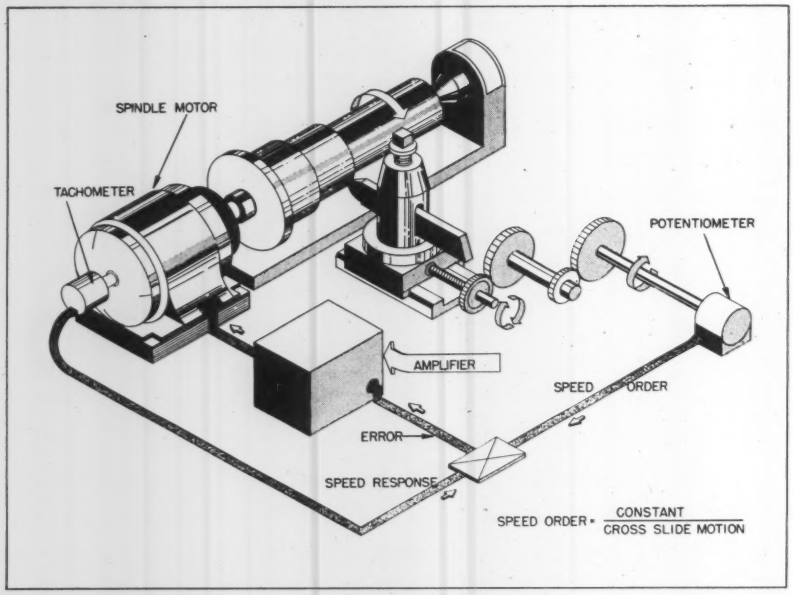


Fig. 4—Spindle drive uses servomechanism control to vary rotational speed of work and provide constant-speed surface cutting

will have exceedingly low response to inputs varying faster than a specific frequency. Thus, since the frequency of variation for variables in most machines or processes is very low, any extraneous high-frequency noise or jitter will not affect the servo.

That a servo has muscles is readily apparent; it takes only a few microwatts to produce as many horsepower as the job requires. The input signals can be remotely located, utilizing wire or radio links if required. Dangerous or inaccessible machines or processes may thus be safely controlled from a distance.

Capabilities of servos are numerous. One type of service is illustrated by the simple angle repeater servo shown in *Fig.* 3. The problem here is to continuously and accurately position a rotary load according to an angular order from a remote station. This particular servomechanism might be used in analog computers where the power requirements are not in excess of a few watts.

Angle transmission from the remote station to the servo utilizes a conventional 60-cycle selsyn system. The shaft angle (θ_i) of the synchro generator (*SG*) is repeated at the synchro control transformer (*CT*) shaft when the voltage output of its rotor leads (R_1 and R_2) is a null. The *CT* is directly coupled to the load which has an angular heading designated θ_o. For small angles, the *CT* output voltage is proportional to the difference or error between θ_i and θ_o. Also, the polarity of the voltage corresponds to that of the angular error.

One way of providing accurate tracking, θ_o to θ_i, is to connect a voltmeter to the *CT* leads, R_1 and R_2, and manually rotate the *CT* shaft so as to maintain a continuous indicated null. Manual tracking is, of course, quite unnecessary. Automatic tracking can be easily accomplished by connecting the *CT* rotor leads to the input of the servo controller. Should an error exist, the signal from the *CT* is multiplied many times by the amplifier which applies a powerful voltage to the servo motor (*SM*). The motor responds with a proportionate torque and drives the load and *CT* to correspond with the order.

The servo motor is a miniature 2-phase induction motor of the high-resistance rotor type, especially designed for servo applications. It is essentially a low torque, high-speed device and therefore must be geared down to the load which operates at high torque and low speeds. Good gearing design is an essential requirement for optimum servo performance. The major design consideration, depending on the particular servo application, might be accuracy, size, weight, inertia, backlash, friction, or compliance.

The amplifier, in contrast to most audio amplifiers, operates at a single frequency of 60 cycles. Standard unitized construction is used with design directed to considerations of long life, high stabilized gain, maximum power output and consistent performance.

High-gain servos, such as this example, would tend to hunt or oscillate continuously if some form of damping were not provided. The damping generator (*DG*) accomplishes electrically what a viscous damper connected to the motor shaft would do mechanically in limiting or preventing hunting. There are many alternative means for damping including the popular and inexpensive electric network damps.

Where high accuracy is important, the limiting component is usually the synchro system. In such cases, so-called two-speed systems are employed. For example, a 1 and 36-speed system would use, in addition to the *CT* provided at the load speed which would be 1, a *CT* geared accurately to a ratio 36 times that of the load. At the remote station, a *SG* geared to a ratio 36 times that of the 1-speed *SG* and dial would also be provided. When the servo is off synchronism by several degrees, the 1-speed *SG* and *CT* are in control and act to drive the servo close to synchronism. At this point, the 36-speed units take over automatically and maintain control. The angular error introduced by this high-speed synchro system is divided by the gear ratio of 36. Thus, where normally in a single-speed system maximum tracking errors of say 30 minutes might be

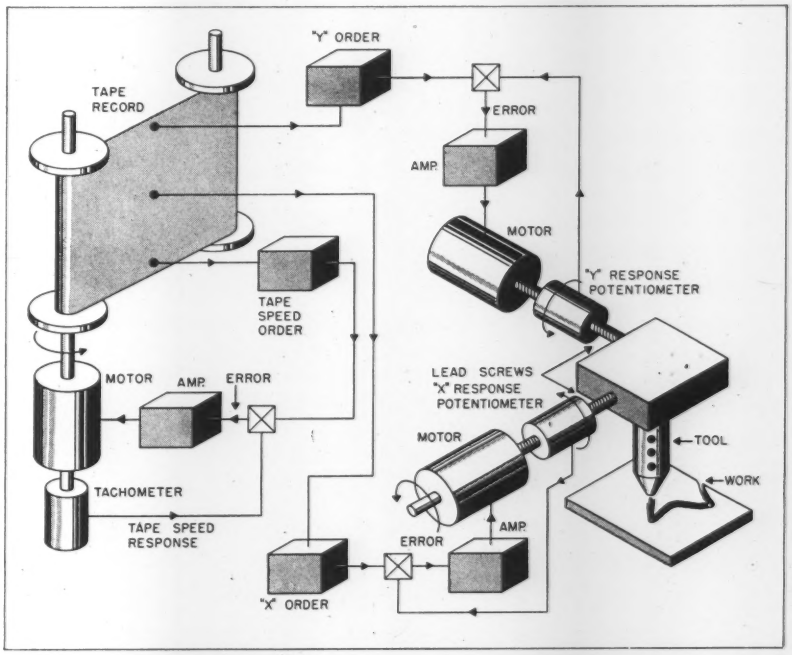


Fig. 5—Automatic contour cutting uses servos to position cutting tool in rectangular coordinate system according to orders from punched tape and requires no master pattern or special linkage

expected, the 2-speed system would attenuate this error to less than ½-minute.

Control Applications: There are four basic operations in an automatic factory:

1. Machine control
2. Machine loading and unloading
3. Tool change
4. Materials handling.

Just where servomechanisms can be most effectively used in each of these operations is a problem for the engineer and designer. One application to machine control using the servo described previously, *Fig. 2a,* is shown in *Fig.* 4. For the large cylindrical workpiece mounted in the lathe, if the spindle were to be driven at a constant rpm, the lineal cutting speed at the surface of the work would be a maximum at the start and would decrease directly with the radius. This surface speed variation would be objectionable for two reasons: (1) Machining time would be increased, and (2) optimum metal cutting speed would occur only at the start.

With a closed-loop speed control system, it is a simple matter to achieve a constant lineal cutting speed. A potentiometer is geared to the cross slide so that it produces a voltage inversely proportional to the radius of the work piece or its equivalent, the cross slide motion. This voltage is used as an order to the spindle drive servo. The rotational speed of the work is thus increased as its radius decreases and a constant surface cutting speed is maintained.

In this application the servo is acting in two important roles: (1) As an equation solver, and (2) as an automatic drive maintaining the correct spindle speed as ordered by the cross slide potentiometer. It should be noted that this type of drive would be applicable in a variety of problems; for instance, paper reeling or steel rolling.

Another machine control application for servomechanisms would be in automatic contour cutting, *Fig.* 5. In this system it is desired to cut contours of any shape without a master and without any pantograph type linkage system. The drive uses a rectangular coordinate (x,y) system. Separately driven x and y lead screws position a single chuck holding a suitable cutting tool or flame cutter. The work is mounted on a stationary table. A response potentiometer furnishes a voltage which is an exact measure of the drive position with respect to a baseline. If this voltage opposes a calibrated order voltage in the null circuit of the servo, the drive will automatically adjust itself to the ordered position.

The order may be derived from some device like a "piano roll" punched tape or a magnetic tape. On this tape, the simultaneous x and y co-ordinates of the desired contour, are recorded in two rows. These quantities produce, on a digital basis, accurate voltages which order the respective drives to the proper point on the contour. A system like this lends itself naturally to scale change by merely scaling the voltage excitation of the response potentiometer.

Cutting speed depends on the speed of the tape drive. Variable-speed control of cutting is accomplished by recording on a third row of the tape the instantaneous speed required. Orders are transmitted to a lightweight tape-drive servo. This feature might be particularly useful in cutting a casting of variable cross-section.

Accurate generation of noncircular gears has been achieved automatically with servomechanisms. A Fellows gear shaper has been adapted to this job using standard synchros, motors, switches, etc., *Fig.* 6. Gear cutting orders are transferred digitally from specifications to a movie film. The film is projected on a bank of photoelectric cells and the cutting orders relayed to the servos which slave the gear cutting mechanism. A set of noncircular gears cut by this gear shaper is shown in *Fig.* 6. Noncircular gear cutting with this automatic gear shaper can be used to produce masters or production lots.

Machine loading and unloading present further problems to the control engineer. If the servo is considered as an automatic arm programmed by some form of computer, it should be possible to imitate many of the functions of the human operator. In addition the

(*Continued on Page* 217)

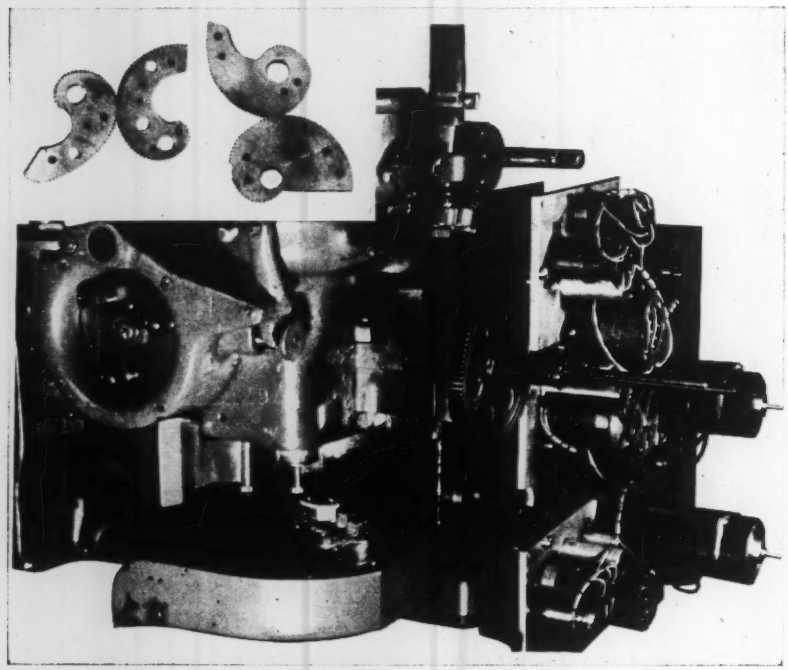


Fig. 6—Fellows gear shaper, which has been adapted to servo control can be used to cut noncircular gears such as shown in insert

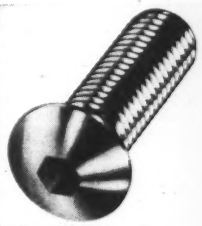
NEW PARTS AND MATERIALS

. . . presented in quick-reference data sheet form for their convenience of the reader. For additional information on these new developments, see Page 181

BUTTON-HEAD SOCKET SCREW 1

. . . high strength, streamlined appearance

Standard Pressed Steel Co., Box 102, Jenkintown, Pa.



For use particularly where countersinking is impractical, this screw can be used without loss of strength instead of screws with higher heads.

Size: No. 8 (0.164-in.), No. 10 (0.190-in.), ¼, $\frac{5}{16}$ and ⅜-in. thread diam in NF and NC series; ½ and $\frac{5}{8}$-in. diam in NC series; 4 to 7 different lengths, depending on size.

Service: For fastening with "streamlined" appearance and high strength; low head promotes safety and ease of cleaning.

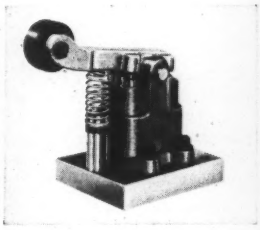
Design: Alloy-steel buttonhead socket; precision-rolled threads; threaded to head of screw; heat treated.

For more data circle MD 1, Page 181

CAM VALVE 2

. . . small, compact and rugged

Ross Operating Valve Co., 120 E. Golden Gate, Detroit 3, Mich.



A small companion model to the company's regular line of cam-operated valves, this unit is especially suitable for low-volume applications.

Designation: 63c.

Size: ¼-in. pipe size; base, 3½ in. long, 3 in. wide; 3⅝ in. high excluding cam roller; $\frac{15}{16}$-in. lever travel; lever length, 3⅛ in.

Service: Air or hydraulic control at pressures from 10 to 150 psig; force required on roller, 11½ lb.

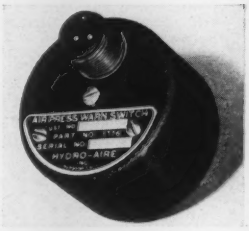
Design: Four-way; synthetic rubber seats; hardened wear points in lever.

For more data circle MD 2, Page 181

PRESSURE SWITCH 3

. . . for electrical control or warning systems

Hydro-Aire Inc., 3000 Winona, Burbank, Calif.



Air, aircraft fuels, hydraulic fluids or lubricating oils can actuate the switch.

Size: 2 in. diam; 2.16 in. long.

Service: Switch actuation at pressures from 0 to 1500 psi; ambient temperatures, −65 to 160 F; altitude to 50,000 ft; max current, 1.0 amp at 50,000 ft. altitude and 28 v dc.

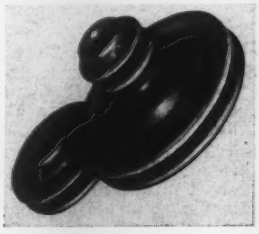
Design: Bourdon-tube type.

For more data circle MD 3, Page 181

MOLDED SHEAVES 4

. . . wear well on light machinery drives

W. C. Products Inc., 1748 Berkeley St., Santa Monica, Calif.



Having a hard wearing surface, these V-belt sheaves weigh less and run quieter than metal pulleys.

Size: 2 to 6 in. OD in ½-in. increments; bore sizes, ½, ⅝ or ¾-in.; width, $1\frac{7}{16}$ in.

Service: For light machinery drives; hard surface is unaffected by moisture and oil, resists heat; sheaves run quietly.

Design: Pressure-molded to close tolerances from fibrous-material filled plastic.

For more data circle MD 4, Page 181

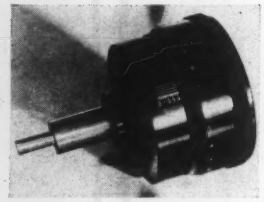
NEW PARTS AND MATERIALS

MICROMETER HEAD 5

. . . measures to 0.000025-inch

Boeckeler Instrument Co., 39 E. Rillito St., Tucson, Ariz.

The spindle on this head does not rotate, minimizing wear at the measuring surface.



Size: 3⅝ in. diam; 5 in. long with spindle retracted.

Service: Gaging directly to 0.0001-in. and by vernier to 0.000025-in.; lead screw has overall accuracy of 0.00005-in., with compensation provided by individual setting of dial-mounted scale and vernier to accuracy of 15-millionths in. at time of calibration; wear between spindle and part against which it will bear is minimized; adjustment provided for lead-screw tension, eliminating backlash in either direction of rotation.

Design: Nonrotating spindle; tungsten-carbide disk and ball contact between spindle and head, minimizing internal wear; aluminum barrel and thimble, with black anodized finish and white lines and figures.

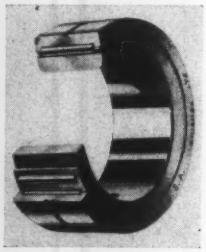
For more data circle MD 5, Page 181

NEEDLE-ROLLER BEARINGS 6

. . . combine features of both types

Roller Bearing Co. of American, Whitehead Rd., Trenton 3, N. J.

Having the dimensional advantages of needle bearings, these new units maintain roller alignment and can be mounted in any plane.



Designation: Pitchlign.

Size: Without inner races—0.75 to 9.25 in. shaft diam; with inner races—0.50 to 8.00 in. ID; 1.25 to 11.125 in. OD, respectively, in both types.

Service: Rollers stay aligned when bearing is mounted in any plane; rollers will not skew or lock under shaft misalignment or deflection, and produce thrust loads; no stress on cage due to end thrust on rollers; initial operating clearance is maintained, since races and cage have same coefficient of expansion.

Design: Small-diameter rollers are guided at their centerlines by a one-piece steel cage; inner and outer races of SAE 52100 steel; outer races have double flanges which support and guide the cage; rollers are located axially by direct contact with outer-race flanges; retaining lips on cage do not contact rollers after shaft or inner race is inserted in bearing.

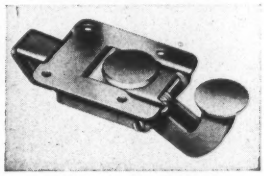
For more data circle MD 6, Page 181

FLUSH LATCH 7

. . . also provides grip for opening door

Hartwell Co., 9035 Venice Blvd., Los Angeles 34, Calif.

Finger-tip pressure on the forward pushbutton automatically raises the rear button, providing a sturdy grip.



Designation: H-4100.

Size: Mounting plate, 1.850 in. long, 1.502 in. wide; 0.850 in. deep; button offsets (door thicknesses) from 0.025-in. through 0.188-in. available, with 0.031-in. (22 ga), 0.063-in. (16 ga), 0.125-in. (11 ga) or 0.188-in. (7 ga) as standard; 0.553-in. max bolt engagement.

Service: Flush closing of panels, doors, access plates; two circular cutouts, required for mounting, easily made with drill.

Design: Spring-operated flush latch which can be self-closing; available in (1) stainless steel with cadmium-plated music-wire or Inconel spring, (2) cadmium-plated cold-rolled steel latch and yoke with stainless pushbuttons and music-wire spring, or (3) anodized 24ST aluminum with music-wire spring; spring has 3 lb-in. torque.

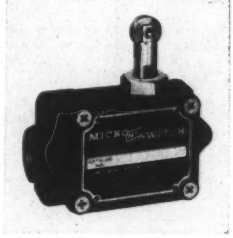
For more data circle MD 7, Page 181

ROLLER-PLUNGER SWITCH 8

. . . actuated by cams with severe rise

Micro Switch Div., Minneapolis-Honeywell Regulator Co., Freeport, Ill.

This switch has the capacity to make or break steady-state currents up to 20 amp and to handle in-rush currents up to 75 amp.



Designation: BAF1-2RQ9-LH, -RH.

Size: 4 in. long, $1\frac{5}{32}$ in. wide, $3\frac{33}{32}$ in. high; weight, 0.55-lb, approximate.

Service: Operation by cams with rise (approach angle) up to 30 deg; sealed against dust, dirt, oil and moisture; UL ratings as follows; ¾-hp at 115 v ac, 1½ hp at 230 v ac; 20 amp at 125, 250 or 460 v ac; 10 amp at 125 v ac with tungsten-filament lamp load; ½-amp at 125 v dc, ¼-amp at 250 v dc; operating force, 2½ lb max; release force, ¾-lb min; pretravel, $\frac{5}{32}$-in. max; differential travel, 0.010-in. max; overtravel, 0.187-in. min.

Design: Roller-plunger actuated, snap action; single-pole, double-throw; plunger assembly—on left side of enclosure with -LH, right with -RH—can be aligned with cam then clamped by tightening nut; die-cast aluminum enclosure; three ¼-in. holes on flange at back of enclosure for mounting.

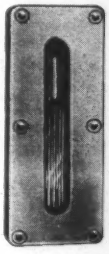
For more data circle MD 8, Page 181

NEW PARTS AND MATERIALS

SIGHT GAGE 9

. . . mounts flush in housing

Rucker Mfg. Co., 4516 *Hollis St.*, *Oakland* 8, *Calif.*



Many variations can be supplied in length and materials.

Designation: Reflex.

Size: 4½ in. sight-glass length, standard; lengths to 12¾ in., special.

Service: Observing liquid level or internal activity in tanks, vats or vessels; level can be observed from 15 deg off vertical or horizontal; standard gage is for temperatures to 500 F, vacuum or pressure to 15 psi.

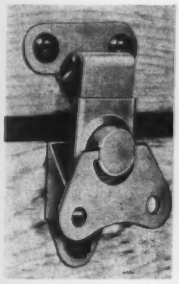
Design: Standard model has cast-iron housing, fluted temperature-resistant sight glass and asbestos gasket; available with transparent glass, cast stainless-steel or vitreous-enameled cast-iron housing; available with sanitary gaskets for food industry.

For more data circle MD 9, Page 181

LOCKING LATCH 11

. . . for waterproof, splashproof sealing

Simmons Fastener Corp., *N. Broadway*, *Albany* 1, *N. Y.*



Having high closing pressure for its small size, this latch insures positive sealing when used with gaskets.

Designation: Link-Lock 3.

Size: Engagement latch, $2\frac{1}{16}$ in. long in open position, 1¾ in. wide, $\frac{9}{16}$-in. thick; ¼-in. bolt travel.

Service: For preloaded closure with up to 90-lb pull-down pressure; 300-lb tension loading; withstands −70 F temperature; ensures watertight, splashproof seal with gasket; lies flat when locked.

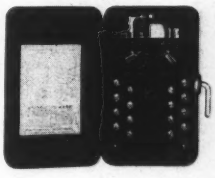
Design: Springless latch is flipped open or shut with 180-deg turn of wing nut; heat-treated alloy steel; engagement latch detail can be varied.

For more data circle MD 11, Page 181

ELECTRONIC TIMER 10

. . . provides 4 basic timing methods

Photoswitch Inc., 77 *Broadway*, *Cambridge* 42, *Mass.*



Extremely flexible in application, this timer is designed for long life repeat-cycle operation.

Designation: 30HL1

Size: 6¾ in. wide, 9⅝ in. high, $4\frac{7}{8}$ in. deep; weight, 8 lb.

Service: For machine timing or processing control; provides 4 basic types of timing—interval, delayed action, automatic repeat, or programming; by changing external connections to terminal board, variations of these timing combinations are obtained; time intervals from 1/20-sec to 4 min; self-compensating for line voltage changes; accuracy to within 2%; for 115 or 230 v, 50-60 cycles ac; power, 25 w; main contact rating, 10 amp at 115 v ac noninductive, 5 amp at 230 v; auxiliary contact, 1 amp at 115 v ac noninductive, 0.5-amp at 230 v.

Design: Electronic with one vacuum tube and one relay consisting of 2 single-pole, double-throw switches.

For more data circle MD 10, Page 181

VERTICAL MOTORS 12

. . . for single-phase operation

U. S. Electrical Motors Inc., 200 *E. Slauson Ave.*, *Los Angeles* 54, *Calif.*

Centrifugal switches have been replaced by accelerating-type relays in these new designs.

Designation and Size: SCU-C, 1½, 2 and 3 hp; SCU-R, 5 hp.

Service: For vertical shaft turbine pumping conditions; relay requires no critical adjustments; bearing grease or foreign particles cannot work into relay; 1800 or 3600 rpm; for 60-cycle single-phase ac; −C for 115/230 v, −R for 230 v; rated at 40C temperature rise.

Design: Vertical hollow shaft; accelerating type relay with double-break contacts is mounted in split-type outlet box located on side of motor; −R has starting condensers, −C has starting and running condensers; solid centrifugally cast rotor; flush-through lubrication; downdraft ventilation.

For more data circle MD 12, Page 181

NEW PARTS AND MATERIALS

LAMINATED PLASTIC SHEETS 13

. . . in continuous strips of desired length

Industrial Organics Corp., 59-31 54*th St., Maspeth* 78, *N. Y.*

One-fifth the weight of steel, this material has an equal tensile-strength to weight ratio.

Designation: Iolyte.

Form: Sheets, rolls or tape.

Size: Thickness from 0.008 to ¼-in.; continuous lengths to specification.

Service: Withstands continuous temperatures to 350 F; good electrical properties; resistant to chemicals; low water absorption.

Properties: Polyester laminate with Fiberglas cloth or mat filler; cotton cloth, Orlon, nylon or other synthetic fiber or cloth fillers available; available in colors, translucent or opaque.

For more data circle MD 13, Page 181

DETACHABLE-LINK V-BELT 14

. . . runs in either direction

Brammer Co., 684 *Broadway, New York* 12, *N. Y.*

Prestretched and full-load tested, these belts have a high coefficient of friction and a wedging action which reduces slip.

Designation and Size: 100-ft lengths on reels;

Part No.	Size (in.)	Weight (lb/100 ft)	Part No.	Size (in.)	Weight (lb/100 ft)
O	⅜	11	C	⅞	35
A	½	16	D	1¼	80
B	⅝	23			

Service: Power transmission with low slip; prestretched to hold size; runs in either direction without jamming; resist oil and heat; tensioning devices not needed.

Design: Links, uniform in camber and dimensions, are made from woven cloth plies impregnated with crude rubber (Neoprene available); convex stud head has high strength; protector washers of buffalo hide are available to fit under stud heads of B, C or D belts to cushion heavy or pulsating loads.

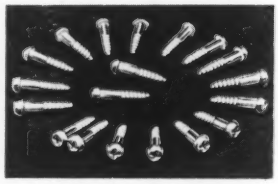
For more data circle MD 14, Page 181

WOOD SCREWS 15

. . . die cast from zinc alloy

Gries Reproducer Corp., 780 *E.* 133*rd St., New York* 54, *N. Y.*

Designed for a wide range of uses, these economical screws can be used in relatively soft materials.



Size and Style: 1 x ⅜-in. with round Frearson heads; others in near future.

Service: For use in soft woods, composition board and plastics; rustproof.

Design: Cast and trimmed, ready for finishing; threads held to close tolerances through use of single-cavity precision dies.

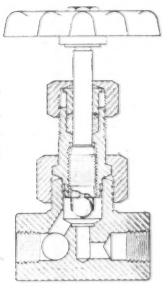
For more data circle MD 15, Page 181

BALL VALVE 16

. . . seats tight at 3000 psi

Foxboro Co., Foxboro, Mass.

Tight, positive shutoff is especially useful on meter manifolds, gage lines, seal chambers, bleed-off connections, sampling connections and lubricator shutoffs.



Size: ¼-in. pipe.

Service: For liquid, gas and steam at pressures up to 3000 psi; stem and packing gland resist corrosion; packing can be replaced without shutting off line pressure.

Design: Ball, globe type; straight-through or angle; 2 or 4 connections; ball, retained at end of stem, closes into a machined conical seat; ball is free-rolling, so that every closing brings a new surface into contact with the valve seat; alignment of ball is piloted by a forged-steel, union-type bonnet, which fits tightly into body; stainless-steel stem and packing gland; preformed graphited-asbestos packing with plastic binder.

For more data circle MD 16, Page 181

NEW PARTS AND MATERIALS

TACHOMETER HEAD 17

. . . measures wide range of speeds

Metron Instrument Co., 432 Lincoln St., Denver 9, Colo.

Having enclosed working parts, this head is suitable for adverse working conditions.

Designation: 56M.

Size: 7¾ in. long, plus 1⅛ in. shaft extension; 5 in. wide; 3¾ in. high.

Service: Measuring rotational or linear speeds where head shaft can be rotated between 100 and 100,000 rpm for full-scale reading; working parts sealed against dirt, abrasives and splashing liquids; can be connected to indicator, recorder or control with up to 1000 ft of No. 20 or larger 2-wire cable; can be mounted in any position; undamaged by wide range of overspeeding.

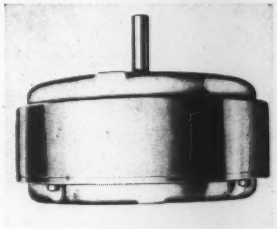
Design: Head shaft actuates a polarity reversing switch so that polarity connection to a capacitor is reversed at a frequency proportional to the measured speed; conduit connector can be rotated to 4 positions; stainless-steel shaft; anodized aluminum head casting; interchangeable.

For more data circle MD 17, Page 181

"WAFER" MOTOR 19

. . . is totally enclosed, fan cooled

Reuland Electric Co., Alhambra, Calif.



An exceptionally short overall length is featured.

Designation: Wafer.

Size: 1/20 through 5 hp.

Service: Speeds from 450 to 3600 rpm; can be mounted within piping or vent in air-moving installations and direct-connected to fan; can be mounted in any position.

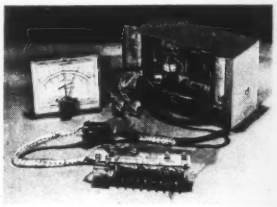
Design: Single-phase or polyphase; mounting by means of "ears," drilled and tapped holes in endbells, or special mountings.

For more data circle MD 19, Page 181

AUTOMATIC CONTROLS 18

. . . for voltage, current or temperature

Assembly Products Inc., Main at Bell St., Chagrin Falls, O.



A complete control assembly is provided, for mounting inside the machine or behind a panel.

Designation: U-Mount-It.

Size: Chassis, 9⅛ in. long, 5½ in. high, 3½ in. deep; meter, 2½, 3½ or 5½ in.

Service: Voltage indication and control in ranges from 0 to 5 mv to 0-500 v dc (ac available); current from 0 to 20 microamp to 0-50 amp; compensated temperature millivoltmeter indication and control from −200 F to 3000 F; higher ranges with external multipliers; control on less than 1 microamp or fraction of a mv; contact setting adjustable over full scale arc; contact rating, 15 amp at 115 v ac noninductive, 7½ amp at 230 v; higher loads or inductive loads with built-in load relay.

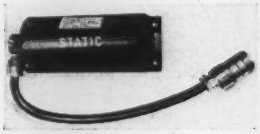
Design: Chassis includes transformer and rectifier power supply and necessary relays, with hinged mounting brackets and dust cover; two control switches, terminal board, meter and necessary leads supplied; specially built.

For more data circle MD 18, Page 181

PRESSURE TRANSDUCERS 20

. . . have high stability and repeatability

Servomechanisms Inc., Post and Stewart Aves., Westbury, L. I., N. Y.



Absence of bearing and sliding contacts eliminates frictional errors, reduces hysteresis and increases repeatability.

Designation: TR101 (static); TR102 (differential).

Size: 7¼ in. long, 2½ in. wide, 2½ in high; weight, TR101—36 oz, TR102—38 oz.

Service: Converting static or differential gas pressures to electric signals; TR101 accepts static pressures of 0 to 760 mm Hg, converts to output voltage of 0 to 2.94 v with 26 v excitation; TR102 accepts differential pressures of 0 to 684 mm Hg, converts to 0 to 3.05 v with 30 v excitation; for 400-cycle systems; minimum temperature sensitivity with reliability over wide temperature ranges; vibration effects eliminated; meets requirements of AN-E-19.

Design: Electromagnetic, comprising variable-reluctance magnetic pickoff bridge circuit and cantilever-suspended Bourdon tube of near-zero thermoelastic-coefficient material; gas-pressure change varies reluctance of magnetic circuit to change output; thermostatically controlled heaters eliminate temperature effects.

Application: Precision instrumentation in airborne control systems; analog computers.

For more data circle MD 20, Page 181

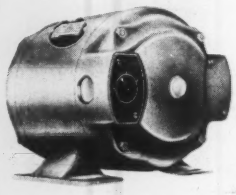
NEW PARTS AND MATERIALS

CAPACITOR MOTORS 21

. . . with built-in voltage and rotation switch

Brown-Brockmeyer Co., 1000 *S. Smithville Rd., Dayton* 1, *O.*

With the built-in selector switch, voltage or direction of rotation can be changed in about 10 sec.



Designation: Power-Poise; Rota-Volt selector.

Size: 1/6, ¼, ⅓, ½, ¾-hp.

Service: Clockwise or counterclockwise rotation and selection of 115 or 230 v operation with selector switch; for 50 or 60 cycles ac single-phase; only 2 leads, permanently connected; 40 C temperature rise, continuous duty.

Design: Capacitor start, induction run; to change voltage or rotation, motor is disconnected, selector knob center screw is loosened, knob is pulled out, turned and pushed in, and center screw is tightened; open or totally enclosed; rigid or resilient mounting; face or flange mounting available; manual or automatic thermal overload protector can be furnished.

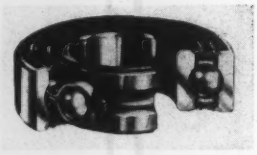
For more data circle MD 21, Page 181

SEALED BALL BEARINGS 22

. . . interchangeable with nonsealed bearings

SKF Industries Inc., Philadelphia 32, *Pa.*

Effective sealing, with light contact and low friction, is provided by flexible Du Pont Fairprene.



Designation: Red Seal; 6200 to 6212, RS or 2 RS; 6300 to 6309, RS or 2 RS.

Size: SAE widths, with dimensions as follows;

Number	ID	6200 Series OD	6200 Series Width	6300 Series OD	6300 Series Width
	(in.)	(in.)	(in.)	(in.)	(in.)
00	0.3937	1.1811	0.3543	1.3780	0.4331
01	0.4724	1.2598	0.3937	1.4574	0.4724
02	0.5906	1.3780	0.4331	1.6535	0.5118
03	0.6693	1.5748	0.4724	1.8504	0.5512
04	0.7874	1.8504	0.5512	2.0472	0.5906
05	0.9843	2.0472	0.5906	2.4409	0.6693
06	1.1811	2.4409	0.6299	2.8346	0.7480
07	1.3780	2.8346	0.6693	3.1496	0.8268
08	1.5748	3.1496	0.7087	3.5433	0.9055
09	1.7717	3.3465	0.7480	3.9370	0.9843
10	1.9685	3.5433	0.7874	.....	.....
11	2.1654	3.9370	0.8268	.....	.....
12	2.3622	4.3307	0.8661	.....	.....

Service: Seal is not affected by petroleum-base lubricants, normal operating temperatures or aging.

Design: Single-row, deep-grove; Du Pont Fairprene seal, either single (RS) or double (2 RS), has flexible lip which touches smooth, uniform chamfer of inner ring; rigid staked retaining rings.

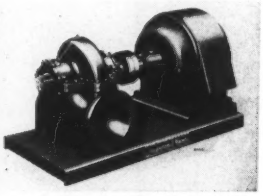
For more data circle MD 22, Page 181

CENTRIFUGAL PUMP 23

. . . compact and totally enclosed

Ingersoll-Rand Co., Dept. CAM, 11 *Broadway, New York* 4, *N. Y.*

Double shaft seals provide more efficient sealing and decrease shaft length.



Designation: DMD (medium heads); DHV (high heads).

Size: 3, 4, 5 and 6 in. pipe sizes.

Service: For general hydraulic service at temperatures to 200 F, capacities to 2100 gpm, pressures to 150 psi; double seal has long service life when pump handles abrasive liquids, since external sealing liquid is injected to the seal box under pressure; seals prevent air leakage; shaft length is decreased, increasing rigidity; points of stress concentration on shaft are eliminated, increasing fatigue life.

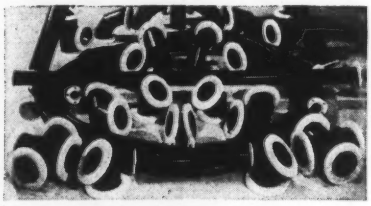
Design: Single-stage, double-suction; double mechanical shaft seals with prelubricated cartridge-type ball bearings; bronze impeller is attached by shrink fit to carbon-steel shaft; shaft is not threaded, reduced or slotted at any point; cast-iron casing.

For more data circle MD 23, Page 181

SEMIFLEXIBLE PLASTIC PIPE 24

. . . resists mineral acids, salts, alkalies

Munray Products Inc., 12400 *Crossburn Ave., Cleveland* 11, *O.*



Competitive with steel pipe in price, this pipe can replace stainless-steel or ceramic pipe.

Designation: Cyclothene.

Size: ½ to 6 in. nominal diam; lengths—25 ft in 4 in. size or larger, 150 ft coils in 3-in., 250 ft coils in 2 in., up to 400 ft coils in smaller sizes.

Service: For piping mineral acids, salts, alkalies, foods and beverages at temperatures to 150 F; unaffected by temperatures to −50 F; physical properties at 70 F as follows; ultimate tensile strength, 1800-2000 psi; yield point, 1200-1300 psi; elongation, 400-500%; impact strength (Izod), 16 ft-lb per in. notch; stiffness, 16,000-19,000 psi; modulus of elasticity, 17,000-19,000 psi.

Design: Semiflexible plastic; knurled and insert connectors clamped with stainless-steel bands available, also welded-on flanges and standard pipe-thread adapter for connection to other equipment.

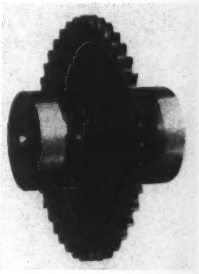
For more data circle MD 24, Page 181

NEW PARTS AND MATERIALS

ROLLER CHAIN SPROCKETS 25

. . . consist of plate sprocket, welded hubs

Cullman Wheel Co., 1344 *Altgeld St., Chicago* 14, *Ill.*



Plates and hubs for all sprocket combinations are carried in stock, insuring fast delivery.

Size: Hub OD's range from 2¾ to 5½ in., max bores from 1⅝ to 3 9/16 in., respectively; sprocket sizes are as follows;

Pitch (in.)	Chain (American Stand.)	Teeth (No.)	OD (in.)
⅜	35	37-96	4.631-11.680
½	41, 40	27-84	4.578-13.678
⅝	50	23-84	4.922-17.079
¾	60	20-84	5.185-20.518
1	80	14-84	4.982-27.326
1¼	100	11-60	5.007-24.601

Service: Power transmission or timing.

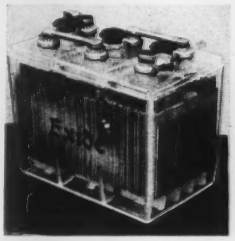
Design: Single strand; plate sprocket (type A), sprocket with single hub (type B), or double hub with central plate (type C); hubs are welded to unhardened steel sprockets; bores are sized to specifications; plate sprockets (type A) supplied with minimum rough bore; standard keyways and setscrews available as extras.

For more data circle MD 25, Page 181

STORAGE BATTERIES 27

. . . for stationary applications

Electric Storage Battery Co., Box 8109, *Philadelphia* 1, *Pa.*



Having transparent cases, these batteries are designed to show at a glance the level of electrolyte and approximate state of charge.

Designation: Exide PLX.

Size: Width, 7 5/16 in.; height, 10⅜ in.; 4 lengths from 4½ to 11⅜ in.

Service: Supplying 50 amp-hr current at 8-hr rate with 2-cell batteries, 100 amp-hr with 3-cell; stationary applications; red, white and blue balls float in electrolyte in chamber when battery is fully charged; when battery is 10 per cent discharged, blue ball sinks; when ⅓ discharged, white ball sinks; when 2/3 discharged, red ball sinks; excessive gas accumulation prevented with venting device; case is stable, resists acids and breakage.

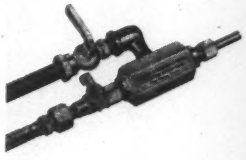
Design: Positive plates are flanked by spun-glass retainers, against which are slotted plastic plate protectors held apart by microporous rubber separators; clear polystyrene case with chambers in outer cell for balls and automatic clear polystyrene venting device in each cell; clear plastic cover is cemented to case.

For more data circle MD 27, Page 181

ATOMIZED-LUBRICANT SYSTEM 26

. . . for cooling, lubricating cutting tools

Henry G. Thompson & Son Co., New Haven 5, *Conn.*



Atomizing clean coolant into a vapor spray, this system is said to consume less oil than circulating systems.

Designation: Atom-Lube.

Size: 6½ in. long, 2½ in. wide without nozzle tubes or mounting bracket; nozzle tubes, 6 and 12 in. long; coolant hose, ¼-in. ID, 4 ft long; air-connection nipple, ¼-in. SPS.

Service: Cooling and lubricating cutting tools; heat dissipation due to air jet, plus deposit of a closely adhering film, permits longer tool life, faster cutting speeds and improved cutting quality; atomizes any coolant liquid, from water to heavy machine oil; coolant spray can be directed to hit edge of cutting tool at any angle; requires 30-35 psi air pressure when drawing coolant from elevated container, 60 psi when drawing from container mounted below valve.

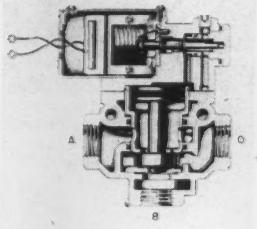
Design: Vapor-spray valve; supplied with mounting bracket, matched flexible nozzle tubes, coolant hose and air-connection nipple; mounted in any position.

For more data circle MD 26, Page 181

SOLENOID VALVE 28

. . . "fails safe" under all conditions

Hannifin Corp., 1116 *S. Kilbourn Ave., Chicago* 24, *Ill.*



By utilizing a differential-pressure principle in both the pilot and master valve design, springs are completely eliminated.

Designation: B-3.

Size: ⅜, ½, ¾, 1, 1¼ IPS.

Service: For air pressures from 40 to 125 psi; valve automatically reverses when solenoid is de-energized or air supply to valve is interrupted, since back pressure from cylinder operates both master and pilot valves; coils for 115, 230 or 460 v, 25 or 50/60 cycles ac.

Design: Solenoid operated; 2 or 3-way; normally closed or open by reversing solenoid pilot head; transformer type silicon-iron plunger has anvil of hardened tool steel welded across entire plunger face to prevent spreading of laminations and jamming; replaceable cartridge serves as cylinder for piston and upper seat for poppet, and contains the master piston and poppet.

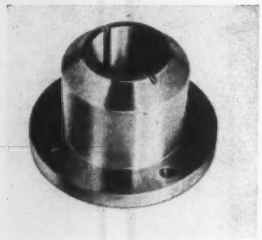
For more data circle MD 28, Page 181

NEW PARTS AND MATERIALS

BRONZE BEARING 29

. . . also serves as seal support

Bronze Bearings Inc., 544 *North Ave. East, Cranford, N. J.*



Although designed for vacuum pumps, this bearing should find applications in hydraulic and pneumatic pumps and motors.

Size: To specifications.

Service: As bearing and support for seal; bearing material has medium tensile strength and good bearing qualities.

Design: Specially designed, cast and machined from high-lead tin bronze (bearing bronze) having the following composition—Cu 83, Sn 7, Pb 7, Zn 3; material is similar to SAE 660, ASTM B30-45T No. 3B and B144-64T No. 3B.

For more data circle MD 29, Page 181

ASBESTOS PACKING 31

. . . Teflon-impregnated for free operation

Mechanical Packing Div., Flexrock Co., 3670-*A Cuthbert St., Philadelphia* 4, *Pa.*

Resiliency of asbestos is combined with Teflon's "antiseizing" properties.

Designation: 401.

Size: Continuous lengths; ⅛ x ¼ in.; $\frac{3}{16}$ x ¼-in; ¼ to 1 in., square; 1 lb spools, 5 or 10 lb boxes.

Service: High resiliency permits tight, lasting seal at low gland pressures, and permits packing different-sized stuffing boxes; will not "seize" a shaft or spindle; temperature, −100 to 500 F; resists hot or cold, diluted or concentrated acids and alkalies and solvents.

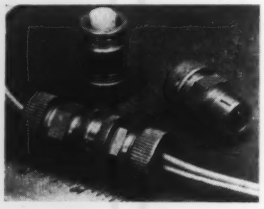
Design: Braid-over-braid white asbestos construction; each strand of asbestos yarn is impregnated with Teflon suspensoid.

For more data circle MD 31, Page 181

LIGHTWEIGHT CONNECTORS 30

. . . resist corrosion, heat, vibration

Titeflex Inc., 500 *Frelinghuysen Ave., Newark* 5, *N. J.*



These small, short electrical connectors save space, eliminate clamps and the need for most right-angle connectors.

Size: 17 shell sizes conforming to AN sizes 8 to 36 inclusive.

Service: For electrical connections; terminals can be removed from block to solder and crimp wiring connections, so that wire connections do not have to be made within the connector shell and slack wire twisted into the connector after assembly; tested to equivalent of 120 hr immersion in salt water without detectable water or salt absorption and no decrease in electrical characteristics; resist vibration and high temperatures.

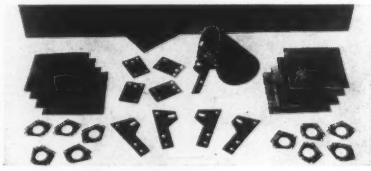
Design: Connector plug and mating receptacle; furnished for cord connections, shielded assemblies and bulkhead or box mountings.

For more data circle MD 30, Page 181

POLYESTER PLASTIC SHEET 32

. . . reinforced with glass fiber

Glastic Corp., 1823 *E.* 40*th St., Cleveland* 3, *Ohio*



This material is claimed to be the only known glass-mat reinforced plastic in production available in $\frac{1}{32}$-in. thickness.

Designation: 940.

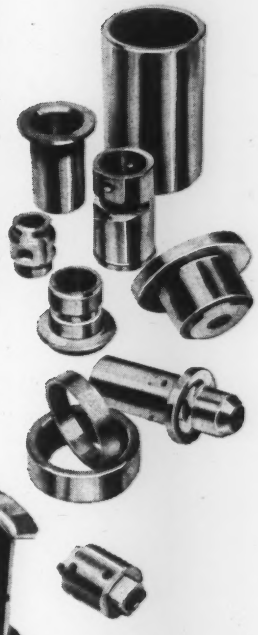
Size: NEMA thickness tolerance standards; standard sheet sizes, 24 x 36 in.

Service: Resists elevated temperatures and arc tracking; dimensionally stable; punches easily, with accurate detail; will not flake or separate; offers body and stiffness.

Design: Glass-fiber reinforced polyester.

Application: Resistance welders; dc motors; circuit breakers; generators; electrical traction-drive equipment; domestic appliances.

For more data circle MD 32, Page 181



JOHNSON SLEEVE BEARINGS

Engineered for YOUR *Application*

JOHNSON BRONZE engineering is far more than designing bearing types and shapes. It is based on thorough studies of your product, its service requirements and your methods of assembly. Johnson engineers start with complete information—load, speed, shock, operating temperatures, lubrication, corrosive conditions and other data. Design is often affected by installation and mounting methods. After this study they may recommend one of several types of sleeve bearings and the correct bearing alloy for your use. And they will design the bearing to your requirements, working closely with your engineers. If this kind of service will be valuable to you, write, wire or call for an appointment.

JOHNSON BRONZE CO. • 525 South Mill St. • New Castle, Pa.

SLEEVE BEARING HEADQUARTERS SINCE 1901

JOHNSON B BEARINGS
Sleeve-Type

BRONZE-ON-STEEL
—copper alloy

STEEL BACK
—babbitt lined

BRONZE BACK
—babbitt lined

CAST BRONZE

ALUMINUM ALLOY

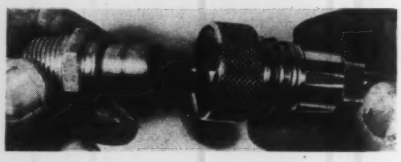
LEDALOYL
—powder metallurgy

NEW PARTS AND MATERIALS

DISCONNECT COUPLING 33

. . . pressure drop reduced 40 per cent

E. B. Wiggins Oil Tool Co. Inc., 3424 *E. Olympic Blvd., Los Angeles* 23, *Calif.*



A change in valve design has produced a noticeable reduction in pressure drop.

Size: Pipe sizes from ⅛ to 1 in.

Service: Quick disconnection of air or fluid lines; self-sealing on socket side, but can be made self-sealing on both sides; withstands temperatures from −65 F to 350 F.

Design: Streamlined inner valve; square-cut synthetic-rubber gasket; aluminum alloy is standard, with brass, carbon steel or stainless steel available.

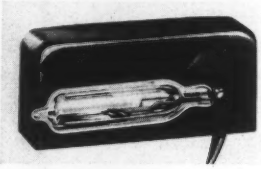
Application: Air tools; motor-driven generators; steam pipes in tire remolders; fuel tank to engine lines.

For more data circle MD 33, Page 181

MERCURY SWITCH 35

. . . embedded in plastic potting compound

Micro Switch Div., Minneapolis-Honeywell Regulator Co., Freeport, Ill.



Protection against mechanical shock, impact or other mechanical hazards is provided.

Designation: 1MP1.

Size: 2½ in. long, ¾-in. wide, 1⅛ in. high.

Service: Sensitive switching with less than 1 deg differential angle; resists mechanical shock or impact; rated 2 amp at 115 v ac, 1 amp at 115 v dc.

Design: Single-pole, normally-open; glass tube is embedded in plastic potting compound; mounting holes accommodate ¼-in. screws and pins.

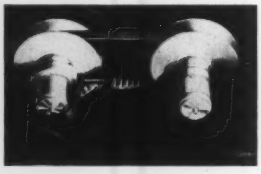
For more data circle MD 35, Page 181

VARIABLE-PITCH PULLEYS 34

. . . operate on fixed shaft centers

Gerbing Mfg. Corp., 11800 *Milwaukee Ave., Northbrook, Ill.*

Manually adjusted, these pulleys give up to 9:1 speed variation without the use of an adjustable motor base.



Designation and Size:

Pulley	OD (in.)	Max PD (in.)	Min PD (in.)	Length* (in.)
550C	5.5	5.25	1.75	4.75
600C	6	5.625	1.875	5.75
750C	7.5	7.125	2.375	7.12
800C	8	7.563	2.52	8.00
1050C	10.625	10.08	2.52	8.00
1100C	11	10.313	3.44	10.44
1250C	12.5	11.813	3.94	11.50
1300C	13	12.313	4.104	12.56

* Excluding grease fitting.

Service: Power transmission in range of ½ to 15 hp at max motor speed; speed-change ratios up to 9:1; used with spring-loaded pulley.

Design: Motor-shaft mounted; axial adjustment of ball-bearing mounted retainer ring fixed on the pulley hub causes pulley to change pitch diameter; U-shaped yoke with threaded control shaft plus torque arm (not supplied) is recommended as control mechanism.

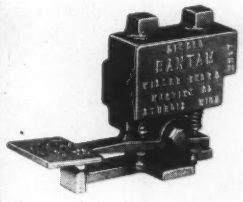
For more data circle MD 34, Page 181

AIR-CONTROL VALVE 36

. . . for foot, hand or cam operation

Wisler Engineering & Machine Co., P.O. Box 204, *Sturgis, Mich.*

Having built-in speed controls, this valve assures smooth, positive cylinder travel.



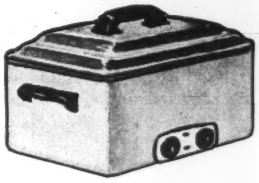
Designation: Sincro Bantam.

Size: ¼-in. NPT ports; height, 4 in., width 1¾ in.; length, 5¾ in. with foot lever, $8\frac{3}{16}$ in. with hand, 6 in. with cam.

Service: Control of double-acting air cylinders up to 3 or 4 in. diam; line pressures to 100 psi; cylinder travel is smooth and controlled; when operated as a 4-way valve the cylinder moves in one direction when lever is depressed, returns when lever is released; lever return spring can be reversed for cam operation with cam below valve.

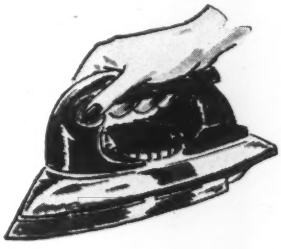
Design: 4-way; 3-way normally open or closed by plugging one exhaust port; foot, hand or cam levers; adjusting screw throttles exhaust air from the cylinder for each direction of travel for positive speed control; Neoprene poppet valves seat against brass and stainless-steel seats.

For more data circle MD 36, Page 181



ROASTERS

TYPE R thermostats give clean, positive make and break of circuit. Also used in range warming compartments, low-wattage water heaters, and electronic devices requiring a high degree of temperature control.

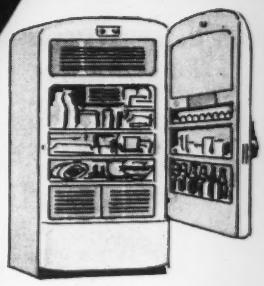


IRONS

TYPE S thermostats feature clean, positive make and break. Electrically independent bimetal prevents artificial cycling for longer thermostat life. Available in adjustable and non-adjustable styles precalibrated for your product.

STEVENS

STEVENS thermostats make appliances perform better—longer



REFRIGERATORS

TYPE W thermostats give *snap-ac* make or break on temperature rise. U widely in butter-warming compartm electronic devices, rectifier fans, apparatus requiring sensitive, pre control of high-wattage heater lo

PERCOLATORS

TYPE M thermostats have bimetal disc that gives *quick* make and break in appliance, apparatus and electronic applications where close control and compactness are essential. Open, hermetically sealed, or neoprene-protected styles for severe dampness.

STEVENS

Stevens makes the largest line of bimetal thermostats in the industry—several hundred styles in all. So even if you have an unusual design problem, check with Stevens first. Probably a standard Stevens thermostat will fill the bill for specifications, price and delivery—and at the same time insure the performance and life of your product. A-5617

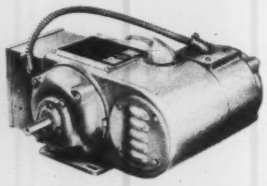
STEVENS manufacturing company, inc. MANSFIELD, OHIO

NEW PARTS AND MATERIALS

VARIABLE-SPEED DRIVE 37

. . . modified for single-phase operation

U. S. Electrical Motors Inc., Box 2058, Los Angeles 54, Calif.



As a modification of the company's VA Varidrive line, this new drive is for fractional-hp operation.

Designation: VA-C

Size: ¼, ⅓, ½ and ¾ hp.

Service: Variable speeds in 10:1 ratio within range from 4 to 10,000 rpm; for 110 or 220 single-phase ac; speed can be changed without stopping.

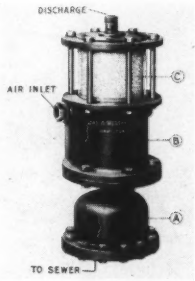
Design: Compact single-phase motor drives V-belt and variable-pitch sheave speed-changing mechanism; turning a control dial changes speed.

For more data circle MD 37, Page 181

SEPARATOR-FILTER 39

. . . removes entrained liquids and vapors

Jas. A. Murphy & Co. Inc., 1421 High St., Hamilton, Ohio



Vapors are removed by the desiccant charge, which changes color when exhausted.

Designation: Triumph AA.

Size: ¼, ⅜, ½, ¾-in. pipe size; 18 in. high.

Service: Removing condensate liquid or vapor, oil or water; pressures to 125 psi; desiccant charges are easily replaced.

Design: Liquids from separator, *B*, are collected by trap, *A* which automatically discharges to atmosphere; oil and water vapors travel to desiccant chamber, *C*; desiccant changes to a deep amber color, beginning at bottom of the chamber, as charge is used up; when color reaches top, charge must be renewed.

For more data circle MD 39, Page 181

REGULATING VALVE 38

. . . provides smooth flow, low turbulence

Leslie Co., 341 Delafield Ave., Lyndhurst, N. J.

Large bowl construction gives smoothly contoured, full-area passages.

Designation: DV.

Size: 1½ to 10 in. pipe size.

Service: Control of pressures to 600 psi; diaphragm operates on 3 to 15 psi control-air pressure from standard instrument controllers; seat rings are renewable and interchangeable without removing valve body from pipe line; renewable guides cannot bind regardless of bolt tightening; valve action can be reversed without changing or machining any parts; bonnets available for temperatures over 500 F or under 30 F.

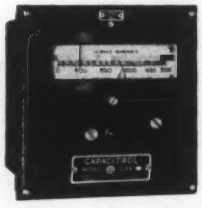
Design: Double-seated diaphragm; 4 sizes of superstructure with from 50 to 210 sq in. diaphragm area; standard ISA face-to-face dimensions; self-aligning guides; trim, type 316 steel plain or Stellited, type 440C hardened stainless, or bronze; in steel valves, seat rings are eliminated and Stellite is applied to main body; Stellited seating surfaces are standard; through-bolt construction in steel valves is standard; flanged stuffing box; cast-iron superstructure; stem is guided with Gilite bushing.

For more data circle MD 38, Page 181

PYROMETER CONTROLLER 40

. . . minimizes on-off variation

Wheelco Instruments Co., 847 W. Harrison St., Chicago 7, Ill.



Hairline control of the variable is achieved by compensating for inherent transfer lags.

Designation: 293 Capacitrol.

Size: 7⅝ in. wide, 8⅛ in. high, 7$\frac{33}{64}$ in. deep.

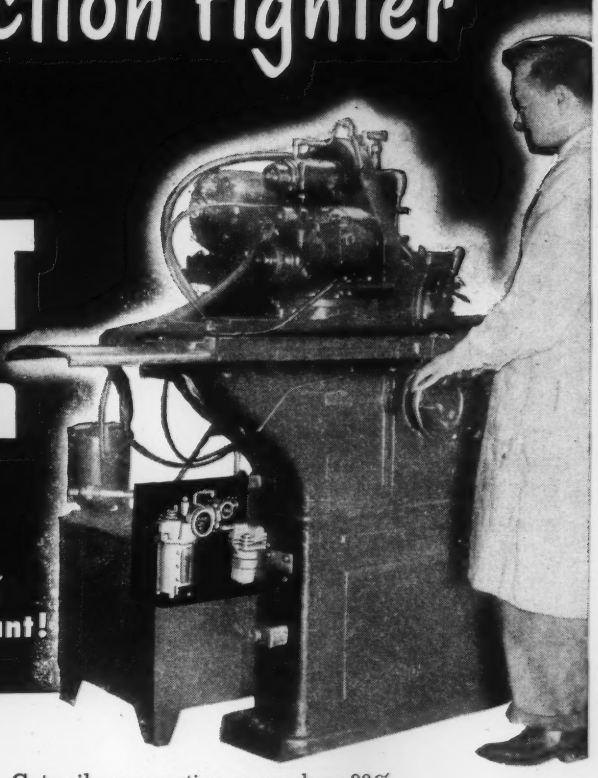
Service: "Straight-line" control of temperature; for 105-125 or 210-250 v ac by changing plug-in selector; contacts rated 10 amp at 115 v and 5 amp at 230 v noninductive; inductive ratings are ½ of noninductive; automatic cold-junction temperature compensation; measurement from any type primary producing an electrical signal, such as a thermocouple or resistance bulbs.

Design: High-resistance galvanometer moves a plate between two coils on the temperature-setting index, changing the frequency of the current flowing between coils; change in frequency actuates a relay to operate controls; supplementary electrical network compensates for heat-transfer lags; can be flush or surface-mounted; wide range of standard scales for various thermocouple calibrations available.

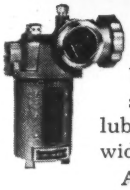
For more data circle MD 40, Page 181

Air-Borne "Friction Fighter"

Alemite OIL-MIST Lubrication



* extends bearing life as much as 17½ times!
cuts oil consumption up to 90%
boosted production 50% at one plant!



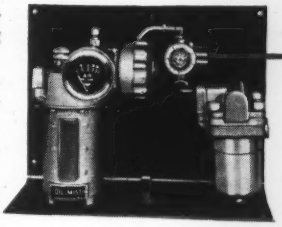
Unbelievably simple! Fully automatic! Designed—by Alemite—to speed and simplify lubrication . . . gain valuable production on a wide range of machinery applications.

Alemite Oil-Mist eliminates waste and the uncertainties of the human element. Air pressure seals bearings. A simple lubricator—with no moving parts—bathes all bearing surfaces with fresh, clean, cool oil film. Reduces the number of oils needed. Cuts oil consumption as much as 90%.

Already this great new Air-Borne "Friction Fighter" has been fully proved by plant installations on a wide variety of machines in many industries. The results are spectacular—in reduced lubrication costs, reduced maintenance costs, reduced "downtime." In one plant* Alemite Oil-Mist has even helped boost production by 50%! Send for booklet offered below telling how you can easily equip *your* machines with Oil-Mist.

**Name on request.*

LUBRICATOR SPECIFICATIONS:



- Oil-Mist outlet ½" fem. p.t. Air gauge registers to 50 psi. Operating air pressure—5 to 20 psi.
- Air regulator reduces from pressures up to 200 psi. Normal air consumption—.7 to 1.2 cfm.
- Range of oils handled—to 1,000 sec. (S.U.V.) @ 100°F.
- Oil reservoir capacity 12 oz. (approximately 1 week supply). Intake filter screen—70 mesh. Fill plug—9/16".
- Material—die cast aluminum body with nylon plastic window.
- Baffle-type water separator—automatic self-dumping. Requires no manual attention—no filter elements to replace. Air inlet ¼" fem. p.t.

delivers oil to bearings 3 ways

1. Oil-Mist as Such. Most commonly applied to any type of anti-friction bearing—ball, roller or needle.

2. Oil in Spray Form. For open and enclosed gears and chains. Spray nozzle partially condenses mist into semi-liquid form and directs the spray onto a concentrated area.

3. Oil in Liquid Form. For plain bearings, slides, ways, vees, cams and rollers. In these applications, condensing fittings are used.

A PRODUCT OF SW STEWART WARNER

Just out! This new Oil-Mist Catalog and Engineering Data Book. Write now for your FREE copy. Alemite, Dept. R-72, 1850 Diversey Parkway, Chicago 14, Illinois.

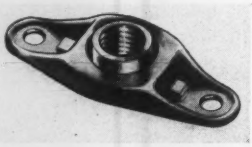
Alemite OIL-MIST Lubrication

NEW PARTS AND MATERIALS

FLOATING ANCHOR NUT 41

. . . lighter than corresponding fixed nut

Kaynar Mfg. Co. Inc., Kaylock Div., Engineering Dept., 820 E. 16th St., Los Angeles, Calif.



These unusually lightweight locking nuts can float radially in their retaining shells.

Designation: F-1000-10.

Size:

Part No.	Thread Size	Length (in.)	Width (in.)	Height (in.)	Weight (lb per 100)
632	6-32	0.969	0.391	0.138	0.24
832	8-32	0.969	0.391	0.164	0.25
1032	10-32	0.969	0.391	0.188	0.26
428	¼-28	1.281	0.500	0.218	0.44
524	5/16-24	1.281	0.516	0.250	0.60

Service: Floating locking nut can move 1/16-in. radially in retaining shell, facilitating alignment in subsequent assembly; upper threads lock the bolt, allowing all threads to carry the actual load; max temperature, 550 F; nut bears directly against mounting surface; conforms to government specifications AN-N-10a and AN-N-5b.

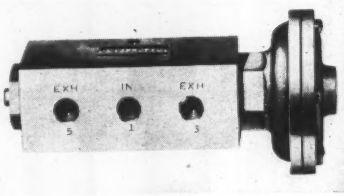
Design: Nuts have elliptical upper threads; both parts are light-gage annealed spring steel, cadmium plated; nuts are spring-tempered to hardness greater than bolt, are lubricated with Silicone lubricant to decrease wear, prevent galling and provide additional corrosion resistance.

For more data circle MD 41, Page 181

DIAPHRAGM VALVE 43

. . . controlled with low-pressure air

C. B. Hunt & Son Inc., E. Pershing St., Salem, Ohio



Capable of being operated by low instrument air pressures, these valves are especially suitable for use in development and research laboratories.

Designation: Quick-As-Wink.

Size: Ports tapped for ⅛ or ¼-in. pipe.

Service: For air, oil or water at line pressures to 125 psi or vacuum; temperatures to 150 F; controlled by air pressures of 12 to 35 psi; valve can be completely disassembled without disturbing main piping.

Design: Diaphragm-operated, spring return, single plunger; 2-way, 3-way, double 2-way, 4-way or 5-way; hollow stainless-steel plunger, with precision-placed ports, is operated by diaphragm; spring return is placed under diaphragm push-plate, permitting open-end exhaust if desired; all parts are balanced; aluminum housing.

For more data circle MD 43, Page 181

PRESSURE TRANSMITTER 42

. . . measures pressure, displacement, force

Wright Engineering Co., 180 E. California St., Pasadena 1, Calif.

Use of associated electronic counter equipment provides a digital output for computers, process control or recording systems.

Designation: Digitran 500, 501, 502.

Size: 500, 1 x 1 x 3 in.; 501 and 502, 3 in. diam, 4 in. long.

Service: Provides frequency output, variable with pressure or other physical variables for control or measurement; ranges available from 0 to 3 psia to 0-5000 psia; accuracy to 1 part in 2000; with associated heterodyne electronic equipment, the frequency output can be counted for a specified period of time to provide a digital output.

Design: Magnetic-field, vibrating-wire; 500 is for telemetering and has no temperature control; 501 has integral temperature control for ambient temperature compensation; 502 has 2 elements to provide reference frequency output and controlled output, and has temperature compensation; associated equipment such as power supply, amplifiers, heterodyne units are available for mounting on 3½ x 19 in. panel.

For more data circle MD 42, Page 181

RINGS AND PACKINGS 44

. . . available in inert Teflon

Packing Div., Flexrock Co., 3609 Filbert St., Philadelphia 4, Pa.

Use of Teflon in these rings and packings gives exceptional resistance to organic or inorganic acids, alkalies or solvents.

Designation and Size: Packings—No. 400, ¼ to 1 in. square—410, ⅛ to 1—420, 1/16 to 1—430, ⅛ to 1—all in 1/16-in. increments; rings—Nos. 440S, 440, 450S, 450, die-formed to specifications from 3/32-in. ID and ¼ in. OD, minimum, also as split rings.

Service: Packing resiliency permits tight seal at low gland pressures; will not "seize" shaft or spindle; 400 for 300 F service—resists caustic alkalies, inorganic acids except nitrating and fluorine-containing, gases except oxygen and fluorine; 410, same, plus fluorine-containing acids and gases; 420, same, except for 450 F and not for gases; 430, 125 F service—resists nitrating acids, higher oleum concentrations; 440, 440 S for 450 F and similar service as 400; 450, 450 S, same, except for free motion where dry graphite is permissible.

Design: 400—braided Teflon jacket impregnated with chemical-resistant lubricant over African Blue Cape asbestos core; 410—same, except braided Teflon core; 420—same, except no lubricant; 430—same, with lubricant for nitrating acids; 440S—endless, die-formed Teflon, lubricated; 440—same, except no lubricant and resilient rings die-formed of interlocked Teflon shreds; 450S—same as 440S, except dry-graphite lubricated; 450—same as 440, except dry-graphite lubricated.

For more data circle MD 44, Page 181

ADLAKE RELAYS AT WORK—One of a series of advertisements on specific ADLAKE applications.

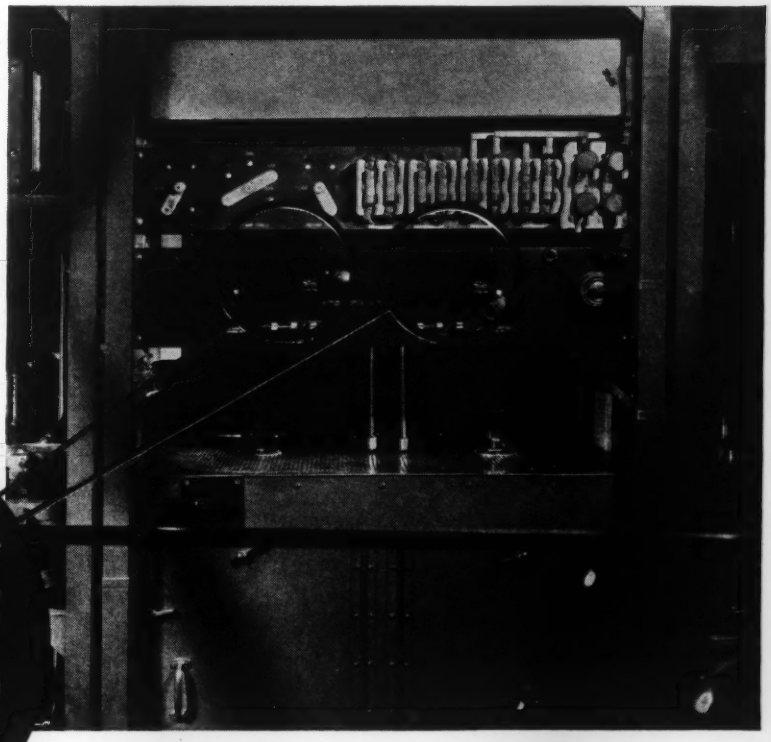
For vital regulation—

Radio Station WAIT uses

Super-Sensitive

Adlake

RELAYS



Operating in conjunction with a thermoregulator, the ADLAKE No. 5000 Relays at Station WAIT control the temperature of the quartz crystals which in turn control the operating frequency of the station.

EVERY ADLAKE RELAY BRINGS YOU THESE ADVANTAGES:

- **HERMETICALLY SEALED**—dust, dirt, moisture, oxidation and temperature changes can't interfere with operation.
- **SILENT AND CHATTERLESS**
- **REQUIRES NO MAINTENANCE**
- **ABSOLUTELY SAFE**
- **MERCURY-TO-MERCURY CONTACT**—prevents burning, pitting and sticking.

ADLAKE'S No. 5000 Relay, which is used by Chicago's Radio Station WAIT in the control of operating frequency, is especially suited to sensitive thermo-regulation. It operates at 115 volts, 60 cycles on only 0.007 ampere—and tests indicate its life to be over 30 million operations!

And, like all ADLAKE Mercury Relays, No. 5000 is hermetically sealed against dust, dirt, moisture, oxidation and temperature changes. Operation is silent and chatterless, and no maintenance whatever is required.

Find out how ADLAKE Mercury Relays can add dependability and reduce costs in *your* business. Write today for your free copy of the illustrated ADLAKE Relay catalog. No obligation, of course. The Adams & Westlake Company, 1128 N. Michigan, Elkhart, Indiana.

Adlake TRADE MARK *95th year* of serving the transportation and building industries

THE

Adams & Westlake

COMPANY

ENGINEERING DEPARTMENT

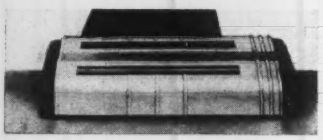
EQUIPMENT

For additional information on this new equipment, see Page 181

PHOTOCOPY PRINTER 45

. . . furnishes dry prints in 30 seconds

American Photocopy Equipment Co., 2849 N. Clark St., Chicago, Ill.



Black and white copies are produced in ordinary office light by new process.

Designation: Auto-Stat.

Size: 21 in. long, 8 in. wide, 5 in. high; copies, up to 11 x 17 inches.

Service: Copies papers, documents or originals printed on one or both sides or on opaque or translucent paper; furnishes reverse reading negative; minimum of 100 copies per hour with inexperienced operator; plug-in operation either ac or dc.

Design: Transfer facsimile principle uses two special coated papers, one sensitive to light and the other not; original is passed through contact printer with sensitive paper and then both coated papers are passed through photocopy printer; sheets peel apart to provide a positive copy of original and a negative; made of stainless steel.

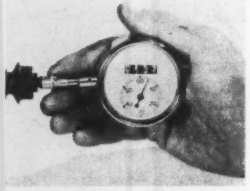
For more data circle MD 45, Page 181

TACHOMETER 46

. . . combines stopwatch, revolution counter

Montgomery and Co. Inc., 53 Park Place, New York, N. Y.

Stopwatch and counter are engaged simultaneously.



Size: Approximately 4 in. long, 1 in. thick; 2½-in. diameter dial.

Service: For measuring speed on rotating parts; suggested running time, 60 seconds; max speed, 5000 rpm.

Design: Gears and drive are brass; nickel plated brass housing; manual turning of knob to reset counter automatically rewinds stopwatch; leatherette case with velvet lining.

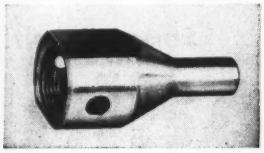
For more data circle MD 46, Page 181

RADIOGRAPHY SOURCES 47

. . . for examining, inspecting metal parts

Tracerlab Inc., 130 High St., Boston, Mass.

Cobalt-60 energy sources, in varying strengths, are available for nondestructive flaw testing of cast and fabricated parts.



Size: 21 mm long, 10 mm wide.

Service: Available in 19 strengths from 50 millicuries to 25 curies; high gamma ray energies permit examination of steel from ½ to 6 in. thick without excessive exposure time; good radiographic sensitivity without need for complicated blocking and filtering; can be placed in complex parts.

Design: Ferromagnetic stainless steel; large threaded hole for remote handling rod; small hole for string suspension; flats machined on sides to prevent rolling; source container, magnetic remote handler, survey instruments and safety equipment available.

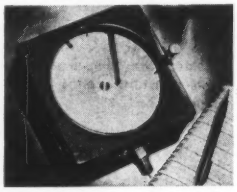
For more data circle MD 47, Page 181

PRESSURE RECORDER 48

. . . measures and records low pressures

Dickson Co., 7420 Woodlawn Ave., Chicago, Ill.

Instrument has calibration adjustment to permit use of charts of varying ranges.



Designation: 3-B Minicorder.

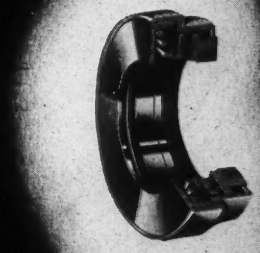
Size: 5¼ x 5¼ x 2¼ in.; weight, 2 lb.

Service: Provides continuous chart record; low chart range, 0-10 in. of water; high chart range, 0-60 psig; all-weather operation; for use with liquids noncorrosive to brass or stainless steel; for pressure, vacuum or combination pressure-vacuum measurement.

Design: Bellows-actuated pen movement; brass or stainless-steel bellows; operating unit assembled to heavy lacquered dial; all parts interchangeable; ¼-in. male bottom connection; can be calibrated for in. of water, oz per sq. in., in. of mercury, ft of liquid, psi, absolute pressure, plus or minus altitude; partial or limited scale charts available; all-metal, rubber-gasketed case.

For more data circle MD 48, Page 181

GITS Unit* SEAL
Now STANDARDIZED



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Gear Reduction Units
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Business Machines

If *you* have a shaft sealing problem, Gits experience in these and many other specific applications can prove of great and immediate value to you.

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*Cartridge Seal . . . pressure balanced . . . requiring only 25% more space than lip-type seals.

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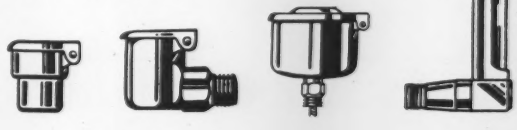
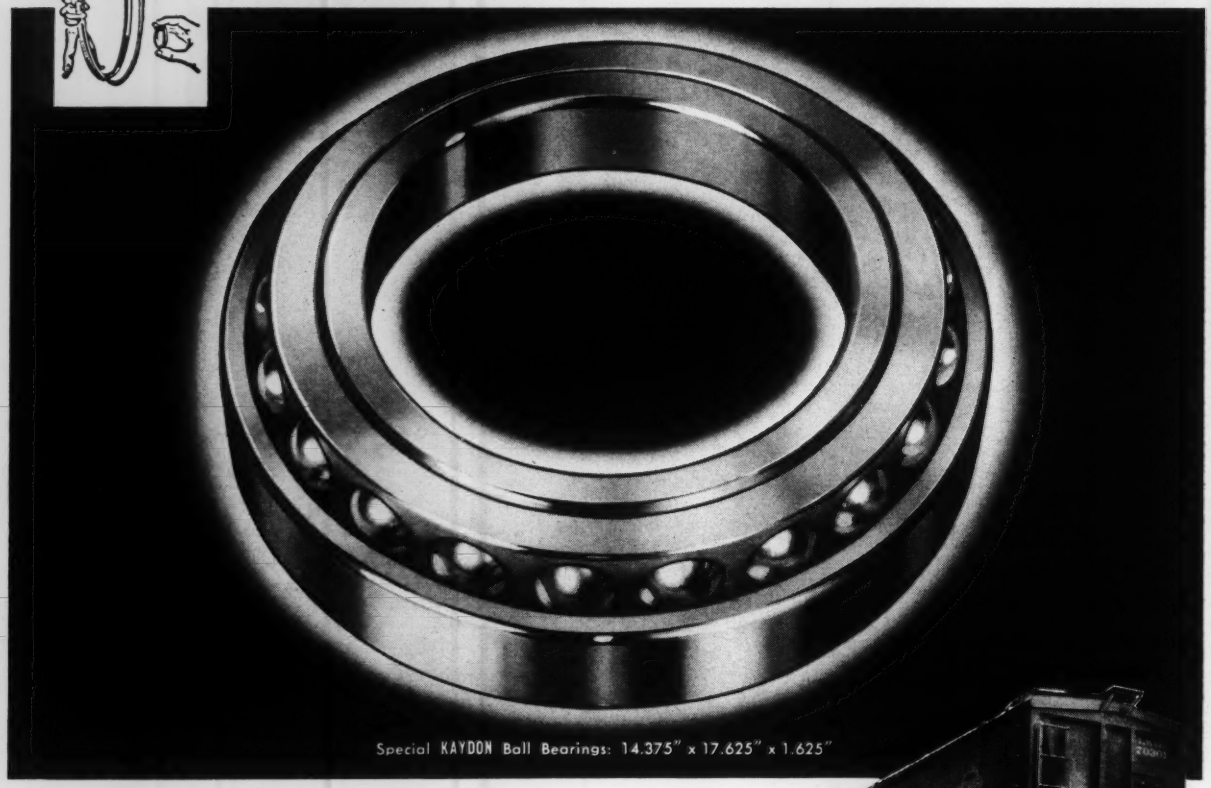


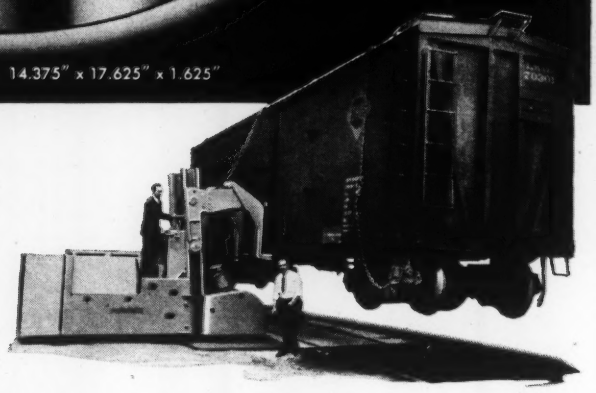
Contact KAYDON of Muskegon

FOR ALL TYPES OF BALL AND ROLLER BEARINGS: 4" BORE TO 120" OUTSIDE DIAMETER



Special KAYDON Ball Bearings: 14.375" x 17.625" x 1.625"

KAYDON-bearinged Lift Trucks pick up 30-ton freight cars



HUSKY KAYDON Special Ball Bearings . . . with static thrust capacity of 120,500 lbs. each . . . help Automatic Skylift Giant Electric Trucks lift multi-ton loads smoothly, efficiently. Made by Automatic Transportation Company, these KAYDON-bearinged trucks live up to their claim to "lighten life's loads." They shoulder heavy responsibilities without flinching!

The precision of these bearings is vital to the steering ease of these powerful lift trucks. They support the heavily loaded trail axle wheels, for steering ease. Diametrical ball clearance is closely held. These special ball bearings are typical of the unusual designs KAYDON engineers create to help machine designers achieve their objectives.

For dependable counsel on Precision Bearings and Needle Rollers, contact KAYDON of Muskegon.

KAYDON Types of Standard and Special Bearings:
Spherical Roller • Taper Roller • Ball Radial • Ball Thrust
• Roller Radial • Roller Thrust • Bi-Angular Bearings

THE KAYDON ENGINEERING CORP.

MUSKEGON • MICHIGAN

PRECISION BALL AND ROLLER BEARINGS

HELPFUL LITERATURE

FOR DESIGN EXECUTIVES

83. Snap-Action Switch

Minneapolis-Honeywell Regulator Co., Micro Switch Div.—Description, electrical ratings, actuating means and characteristics of series BZ-2G make-before-break snap-acting switch are presented in 2-page illustrated data sheet 63. This control will handle 10 amp on 125, 250 or 440-v ac resistive load.

84. High Pressure Pump

Kobe Inc.—High pressure triplex pumps for pressures to 20,000 psi and with displacements up to 62¼ gpm are covered in 6-page illustrated folder. These packaged hydraulic power units have integral motor drives.

85. Rubber Sheet Packings

Raybestos-Manhattan, Inc., Packing Div.—Illustrations and descriptions of pure gum floating stock, Neoprene, red rubber, pure gum stock, black oil-resistant, cloth-inserted and diaphragm sheet packings are offered in 8-page illustrated bulletin. Service recommendations are provided for each type of sheet, and standard thicknesses, packages and weights per square yard are included.

86. Nylon Lined Bearings

Thomson Industries, Inc.—Operating principles, design, advantages and applications of Nylined nylon-lined bearings for rotation and reciprocation uses are set forth in 4-page bulletin.

87. Solenoid Designs

West Coast Electrical Mfg. Corp.—84 detailed engineering drawings are contained in catalog "Solenoid Designs for Aircraft" which is now being made available to design engineers or companies. Prints represent a cross-section of designs over past 12 years.

88. Plaster Mold Castings

Atlantic Casting & Engineering Corp.—How the Atlantalloy plaster mold casting process effects savings in material, grinding, machining and other operations is outlined in 12-page booklet "High Quality Precision Castings for Industry." Process is illustrated step-by-step, and many design facts and specifications are given.

89. Ball & Roller Bearings

Morton Bearing Co.—Complete diameter and size data in both inch and metric standards are tabulated in 10-page bulletin "Ball Bearings and Roller Bearings." Covered are flat and groove race thrust bearings; banded ball thrust bearings; grooved race bearings with both spherical and flat seats; roller thrust bearings; and special type bearings.

90. Stainless Tubing

Babcock & Wilcox Co.—Condensed information contained in technical data folder 143 on Croloy 12 (type 410) and 12-2 (type 414) stainless tubing covers corrosion resistance, mechanical properties, forging, machining, welding, heat treatment and physical properties.

91. Precision Air Regulator

C. A. Norgren Co.—Features, construction data and performance of series 11,400-2 relieving type precision regulator which provides accurate control of air pressure in range of 0 to 2 cfm are contained in single data sheet 482. Regulator is used with air-controlled instruments, or in any process requiring inert gases whose pressures must be precisely regulated.

92. Facts About Plastics

The Richardson Co. — 20-page illustrated booklet "Facts About Plastics, Molded and Laminated" discusses what plastic can do, its limitations, forms of plastics and plastic materials, how laminates are made, ways of molding plastics and proper design of parts. It shows various industrial and consumer applications and covers services offered, as well as properties of laminated and molded Insurok.

93. Multiple-Spline Socket Screws

Bristol Co.—4-page bulletin DM891 is descriptive mailing piece presenting advantages and features of line of multiple-spline socket screws. These fastenings can be made in No. 0 wire size up to ½-in. and are used in products and equipment subject to severe vibration.

94. Hydraulic Remote Controls

Sperry Products, Inc.—Operating principles, general features and illustrations of applications for hydraulic remote controls are included in 4-page bulletin 20-106. Single tube balanced system makes use of series F or H controls.

95. Safety Relief Valve

A. W. Cash Valve Mfg. Corp.—Cash-Acme type F 51 safety relief valve, with high Btu discharge rate, is described and illustrated in bulletin No. 290. It is ASME-approved. Also described is companion type E pressure reducing and regulating boiler feed valve.

96. Engine Power Take-Offs

Funk Aircraft Co.—"Power Take-Offs, Gear Reductions and Accessories for Ford Industrial Engines" is title of 44-page catalog. Each drive is shown by engineering drawing, and prices are included.

97. Steel Casting Specifications

Steel Founders' Society of America—Intended as reference aid to design engineers and purchasers, comprehensive summary chart covers specifications and other pertinent data on more than 70 designated classes of steel castings. Heat treatment, chemical and mechanical properties, tensile strength and hardness are among data given.

98. Snap-Action Thermostat

Stevens Mfg. Co.—In addition to suggested applications, illustrated data sheet L-4144 on snap-acting thermostats also describes operating principle and illustrates it with schematic diagrams. Ratings, typical performance curves, dimensions and construction data are given as well.

99. Pumps & Pump Repair

Yale & Towne Mfg. Co., Stamford Div.—32-page illustrated catalog contains information on various models in Tri-Rotor pump line, ranging from 20 to 200 gpm. Pump operation, pump accessories and descriptions of combination and permutations possible with accessories are covered. Also described is repair parts and service center which has rigid test procedure for repaired pumps.

FOR MORE INFORMATION

on developments in "New Parts" and "Engineering Department" sections—or if "Helpful Literature" is desired—circle corresponding numbers on either card below

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100. Hydraulic Cylinder

Hannifin Corp.—Text and line drawings descriptive of the model U universal hydraulic cylinder designed for tooling, jig and fixture work can be found in 4-page bulletin 112. Installation dimensions, piston areas and output forces are tabulated and mounting instructions are given.

101. Heat Resistant Finish

Midland Industrial Finishes Co.—There's a new and improved silicone-base heat resistant finish for metal products requiring protective coating. Full information regarding this finish, which can be applied by brush, spray or dip methods, is given in 4-page illustrated bulletin "Sicon."

102. Duplicating Machine

Charles Bruning Co.—Practical for moderate reproduction in drafting rooms and plant offices, the Copyflex model 30 copying machine will reproduce anything drawn, written, typed or printed on translucent paper. Full information on this machine is contained in 4-page illustrated folder A-2030.

103. Shaft-Position Indicator

Engineering Research Associates, Inc.—ERA Shaft-Monitor shaft-position indicator systems rapidly detect angular position of rotating shaft and convert indications to digital representation. For full information on operation, accuracy and construction of these systems, get 4-page illustrated brochure PX29536.

104. Reversible Multivoltage Motors

Brown-Brockmeyer Co.—Described in 4-page folder 120-A, Power-Poise capacitor-start induction-run motors in 1/6 to ¾-hp size have been greatly improved by incorporating the new Rota-Volt selector. This built-in control permits quick selection of 115 or 230-volt operation and reversal of rotation of motor. Knob is merely pulled out, rotated to desired operating condition and pushed in.

105. Hydraulic Equipment

Superdraulic Corp. — Descriptions, illustrations and layout drawings of hydraulic equipment such as pumps, cylinders, valves, remote controls, motors, transmissions, presses, power units, test stands and special devices comprise engineering manual "Oil Hydraulic Equipment."

106. Metal Bellows

Solar Aircraft Co.—4-page illustrated bulletin "Aircraft Bellows" gives details on design of Sola-Flex bellows used in turbojet engines, afterburners, hot air ducts and other aircraft assemblies. These stainless steel bellows are fabricated specifically for airframe and engine applications.

107. Air Valves

Rivett Lathe & Grinder, Inc.—A file on air valves is offered to engineers in this 12-page illustrated catalog section 303 which describes 19 different air valve models. Working drawings, specifications and cut-away views are included to facilitate layout of circuits. Hand, foot, solenoid, cam, pilot, speed control and sequence types are suitable for pressures to 150 psi.

108. Electric Motors

Allis-Chalmers Mfg. Co. — Explosionproof fan-cooled and nonventilated motors in ratings of 3 to 100 hp and ½ to 2 hp are described in illustrated bulletin 51B7286A. By eliminating enclosed external air passages, cleaning of motors is simplified. Efficient cooling system adapts motors for use where dust, dirt, fly ash, rain, snow or corrosive atmospheres exist.

109. Lifting Magnets & Separators

Dings Magnetic Separator Co.—Magnetic separation applications, removal of iron from materials, magnetic concentration and purification, heavy media recovery and other uses of magnetic separators are outlined in 12-page illustrated catalog C-5000-B. Also described are lifting magnets of various sizes and types.

110. Electric Power Units

Kato Engineering Co.—Condensed specifications on alternating current generators, motor-generators, ac-dc converters, and alternating and direct current engine driven power plants are contained in 4-page illustrated bulletin "KATOlight."

111. Small Speed Reducers

Metron Instrument Co.—2-page illustrated data sheet No. 7 deals with series 7 antibacklash miniature speed reducers. These units are suitable for applications where backlash between high and low speed shafts must be zero or a very low value.

112. Metallic O-Rings

United Aircraft Products, Inc.—UAP-Wills pressure-filled metallic O-Rings for static installations are subject of 6-page illustrated bulletin. These seals are made in 11/16 to 1½-in. OD with 1/16-in. tube section diameter and up to 20 to 40-in. diameter with ¼-in. diameter tube section.

113. Automatic Centrifugal Clutch

Elgin Sweeper Co.—Design information and general data on the Elgin automatic centrifugal clutch is found in 4-page illustrated bulletin C-252. Clutch is adaptable to any gasoline engine or electric motor. Specifications for four models for ½ to 3½; 3 to 8, 6 to 12 and 12 to 25 hp are given.

114. Liquid and Gas Filters

Commercial Filters Corp.—Brief description of standard Fulflo filters for microscopic clarification of industrial liquids and various gases is included in illustrated condensed catalog PL-200. Principle of honeycomb filter tubes is described. Condensed specifications on wide variety of types and designs are included.

115. Stroboscopes

General Radio Co.—How the stroboscope works and specific applications of different types made by the company are covered in 8-page illustrated form 766-A. Detailed specifications and prices are given for units which serve as stroboscopic tachometer, auxiliary light source and flash unit for ultra-speed photography. Details of contactor for flash synchronization are given.

116. Overload Release Clutch

Overload Release Clutch Co.—"A Positive Safeguard Against Damage Caused by Overloads" is title of 12-page illustrated booklet ORC-52 which gives design details, construction features, specifications and other data. Types for various applications are offered. Clutches are adaptable to every kind of machinery, and there is no limit on bore, torque or speed.

117. Gearmotors

Miehle Printing Press & Mfg. Co., Star-Kimble Motor Div.—Line of gearmotors with motor and speed reducer in single compact housing is subject of 8-page illustrated bulletin B-601. Speed ratios range from 2.5:1 to 97:1 and motors range from ½ to 75 hp. Speed reducers include planetary, offset and right angle worm-wheel types. Various motor types and enclosures are offered.

118. Liquid Drives

G. E. Nelson Co.—File folder on Nelson Liquid Drives contains 8-page illustrated bulletin 6020 on traction type drives, plus data sheets 6040, 6060 and 6080. Drive is a two-rotor unit which transmits torque developed by engine or electric motor at high efficiency. Dimensions and specifications are covered.

119. Computer Memory Component

Alden Products Co.—An electronic component for medium speed pulse techniques and computers, the Static Magnetic Memory, is described and applications shown in 12-page illustrated brochure. No power is needed to maintain storage information and no mechanical motion is needed in recording and pickup.

120. Miniature Ball Bearings

Miniature Precision Bearings Inc.—Detailed specifications for miniature ball bearings for precision mechanisms are presented in 4-page illustrated catalog 52B. Bearings have diameters from 1/10 to 5/16-in. and are made of three metals. Design factors are covered and general and application data are given.

M. D. Numbers

1	21	41	61	81	101
2	22	42	62	82	102
3	23	43	63	83	103
4	24	44	64	84	104
5	25	45	65	85	105
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13	33	53	73	93	113
14	34	54	74	94	114
15	35	55	75	95	115
16	36	56	76	96	116
17	37	57	77	97	117
18	38	58	78	98	118
19	39	59	79	99	119
20	40	60	80	100	120

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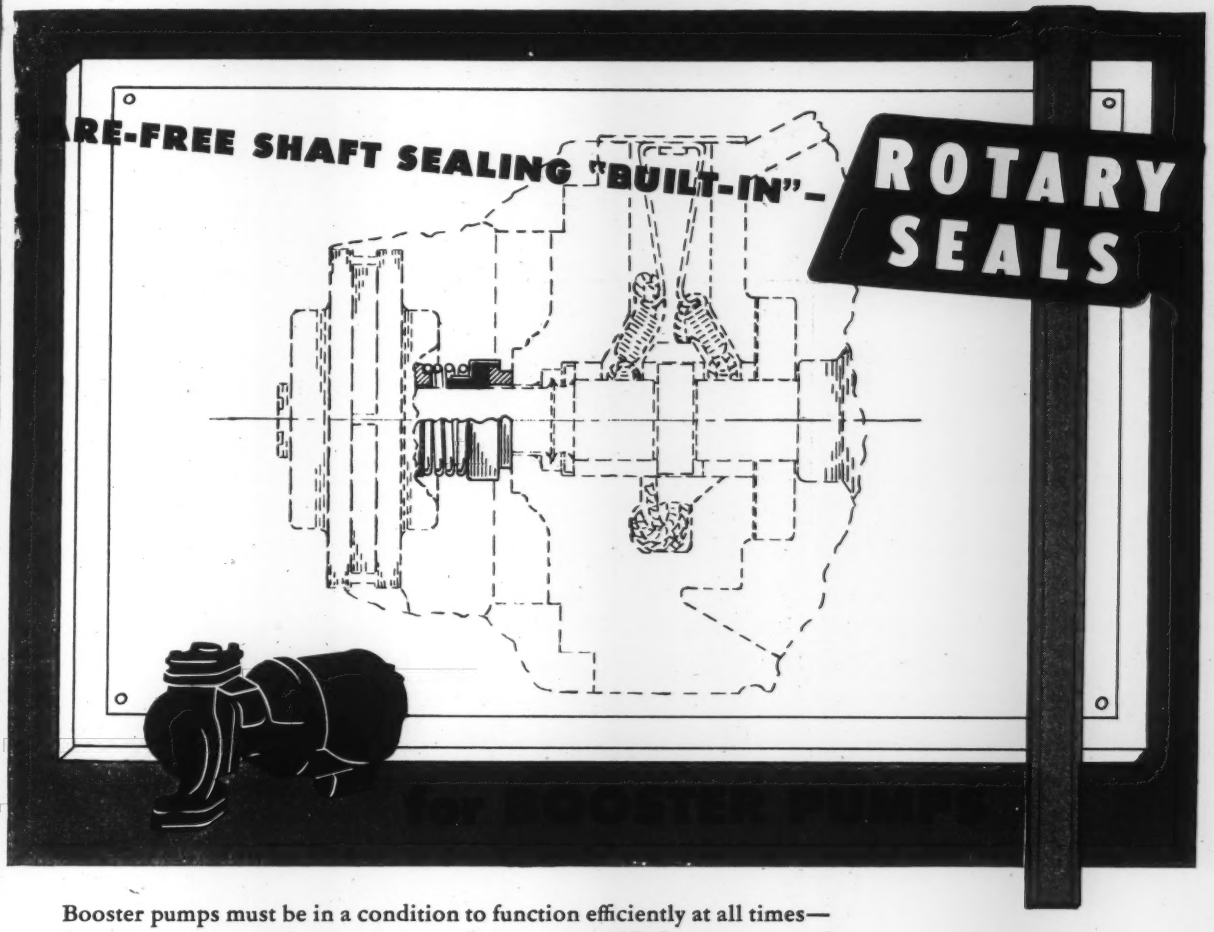


Booster pumps must be in a condition to function efficiently at all times—frequent "time out" for repairs or adjustment would destroy most of their usefulness. That's why leading pump makers make mighty certain that component parts are the best they can get—and why, for many years, ROTARY SEALS have been their choice, for *assuring Certainty in Shaft Sealing*. They have learned that they can count on "care-free" service from ROTARY SEALS, no matter how difficult the operating conditions.

Special adaptations of the time-tested ROTARY SEAL principle have been made to fit exactly the requirements of many different types and models of pumps—to give top efficiency in conjunction with other elements in the pump design. Similarly, "tailor-made" applications have been worked out by our Shaft-Sealing specialists for equipment in many diverse fields, wherever *Certainty in Shaft Sealing* and care-free operation are essential for continuous satisfactory performance.

THE ROTARY SEAL PRINCIPLE

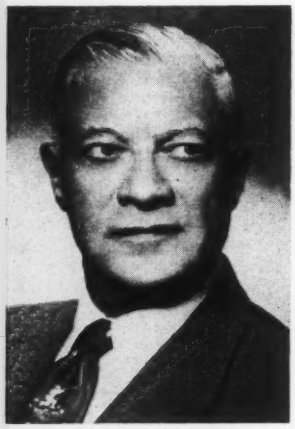
is the original approach to a practical solution of a universally troublesome problem. Our booklet "SEALING WITH CERTAINTY" explains and illustrates the principle. We're glad to send it to you without obligation.

ROTARY SEAL engineers can help with *your* problem, too. Call us in at the drawing-board stage for best results—our broad experience can often suggest the simplest design approach from the Shaft Sealing standpoint.

THE mechanical seals for ROTARY SEAL COMPANY rotating shafts

MEN OF MACHINES

S. L. Crawshaw



Robert M. Moir

John L. Moody

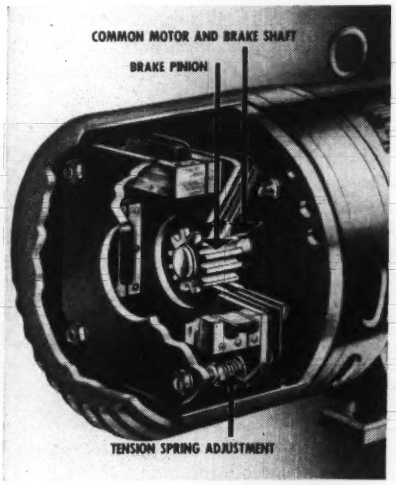
Vice president of the American Gear Manufacturers Association for the past year, **S. L. Crawshaw** was elected president of the association at its 36th Annual Meeting held June 2-4. Mr. Crawshaw has been active in AGMA affairs for many years, having served as a member or as chairman of various engineering and administrative committees. He has spent his entire business career in the gearing industry and at present serves as assistant to the president of the Western Gear Works, Lynwood, Calif. Previously he was chief engineer of the Nuttall Works of Westinghouse Electric Corp., Pittsburgh. Mr. Crawshaw is the author of numerous articles on gear engineering and application, including the Gearing Section of the Twelfth Edition of *Kent's Mechanical Engineers' Handbook,* Design and Production Volume.

Robert M. Moir has been appointed vice president in charge of engineering of W. A. Jones Foundry & Machine Co., Chicago. Mr. Moir graduated from the University of Illinois in 1914. He first became associated with W. A. Jones in 1917, handling general engineering. He was transferred to New York in 1921, and in 1933 returned to the company's main office to supervise research and development. In 1939 he joined the Foote Bros. Gear and Machine Corp. as director of engineering and progressed to manager of sales and engineering, and vice president in charge of engineering. He returned to W. A. Jones last year and is now concerned with development, engineering and sales problems. Active in the American Gear Manufacturers Association, Mr. Moir has been a member and chairman of various engineering and commercial committees and has served on the executive committee.

John L. Moody was recently appointed manager of the research and development department of the Friden Calculating Machine Co. Inc., San Leandro, Calif. Mr. Moody began his career as a design engineer under the tutelage of the late David Sundstrand, inventor of the Sundstrand adding machine, and has since worked in the design and tool engineering of both heavy and light machinery. For the past 23 years he has concentrated exclusively on calculating machines and has done design engineering on various machines for several companies. A patent engineer, Mr. Moody holds many patents on both mechanical and electrical calculating machines. He is the author

Design Details Improve Brakemotor Performance

Efficiency of operation and long service life of integrally built disc brakemotors depends to a large degree on design details, according to Star-Kimble, which pioneered in the manufacture of this type of motor a quarter of a century ago.



Some of these design details, shown in this cutaway view of a Star-Kimble Brakemotor, are:

1. Brake pinion of C4140 moly steel, with a small diameter to cut brake inertia to a minimum. This feature results in quicker stopping of motor—1/5 to 1/2 second in average applications.
2. Convenient location of brake compression springs, permitting easy adjustment.
3. Short, sturdy common shaft for motor and brake, which virtually eliminates the danger of shaft breakage under torsion.

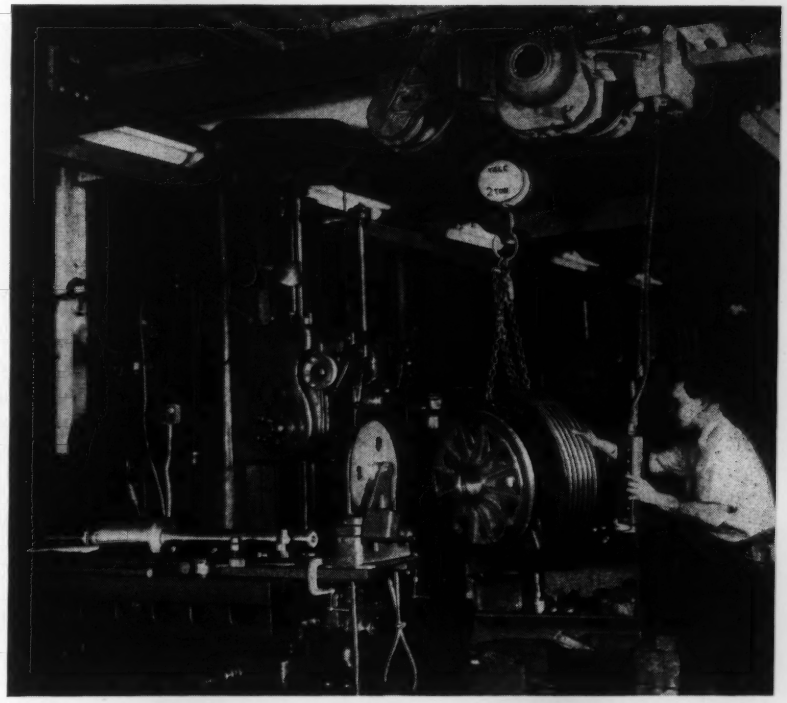
Unit Motor-and-Brake Design

This last feature is made possible by the fact that Star-Kimble Brakemotors are integral units, with motor and brake built together to work together—rather than a brake attached to a motor. Because of this fact, it is possible to design Star-Kimble Brakemotors to give the right combination of motor characteristics, braking torque and kinetic energy absorption for a wide range of service requirements.

The advantages of Star - Kimble Brakemotors have been demonstrated for many years not only in materials handling equipment, but in many other applications where fast, positive accurate stops are required.

Information on design ratings and features of these Brakemotors is contained in Bulletin B-501-A, available on request from Star-Kimble Motor Division of Miehle Printing Press and Manufacturing Co., 201 Bloomfield Avenue, Bloomfield, New Jersey.

Advertisement



HANDLING COSTS CUT by YALE CABLE KING HOISTS

— with Star-Kimble motors on hoist and trolley

ENTHUSIASTIC users of Yale Cable King Hoists report that fast, accurate, reliable handling of heavy loads result in substantial savings in time and costs.

Built for continuous service around the clock, and designed for operation outdoors as well as in, these hoists call for rugged components. Hence Yale & Towne turned to Star-Kimble for the hoist and trolley motors — and Star-Kimble engineers came up with special designs that meet every Cable King requirement.

The 3-phase squirrel-cage hoist motor operates under severe hoisting conditions without overheating — provides plenty of reserve capacity for short-time overloads. Dust-tight, weatherproof construction permits outdoor operation.

Trolley motor is a Star-Kimble Brakemotor that spots the load accurately — no need for time-consuming inching. Adjustable braking torque brings the load to quick, smooth stops.

This is typical of the many ways in which Star-Kimble engineering skill has benefited the designers and users of all sorts of motor-driven equipment.

For information on design and service features of Star-Kimble Squirrel-Cage Motors, write for Bulletin B-201; for Brakemotors, Bulletin B-501-A.

STAR-KIMBLE

MOTOR DIVISION
MIEHLE PRINTING PRESS AND MFG. CO.
201 Bloomfield Avenue Bloomfield, New Jersey

That's a true turnabout for this example of just one of many specially designed Cambridge woven wire conveyor belts. This one carries wet, washed wool through a drying oven to remove moisture and washing chemicals from the fibre. But there's no wild belt travel because the Cambridge Chain Drive design used here prevents the belt from riding from side to side across the pulleys . . . maintains perfectly straight belt movement.

Open mesh of the wire belt permits free, even heat circulation inside the drying chamber. All-metal construction gives longer belt life and lower maintenance costs. The surface of the belt will not stain or mark the wool fibres.

Cambridge Chain Drive Attachment

Whether you're processing textile fibres, foods, chemicals, metal or ceramic products, a Cambridge woven wire conveyor belt can help you cut production costs and maintain product uniformity by combining movement with processing. But don't have the wool pulled over your eyes on conveyor belt design . . . be sure to call in your Cambridge field engineer for his recommendation on the proper—

CAMBRIDGE WOVEN WIRE CONVEYOR BELT—any metal or alloy, mesh or weave.

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of two articles which have appeared recently in MACHINE DESIGN.

♦

Frank J. Dieli has been appointed vice president and chief engineer of Majestic Radio & Television division of The Wilcox-Gay Corp., Brooklyn, N. Y. He heads the engineering and research staffs for Majestic and its subsidiary, Garod Radio Corp., and recently assumed charge of engineering for Wilcox-Gay recording products. Mr. Dieli joined Garod ten years ago and was made chief engineer in 1950. Previously he served as chief engineer for Ansley Radio Corp. and Halson Radio Corp.

♦

To direct all standard product engineering, **Walter M. Hanneman** has been appointed executive engineer by Shakeproof Inc., division of Illinois Tool Works, Chicago. Mr. Hanneman, who has been associated with the firm for more than 20 years, will be located at Shakeproof's St. Charles Rd. plant in Elgin, Ill.

♦

The appointment of **George W. Brown** as executive engineer has been announced by the Wagner Electric Corp., St. Louis. Mr. Brown has been associated with Wagner since 1926, having joined the company as a student engineer following his graduation from Ohio State University. Upon completion of his student engineering training he was assigned to the engineering department, where he specialized in the development, design, manufacture and application of fractional-horsepower motors. Mr. Brown has also served Wagner in various other capacities and in his new position will be responsible for executive direction of the electrical engineering, automotive engineering and metallurgical and chemical departments.

♦

Formerly vice president and chief engineer, **John C. Sharp** has been elected president, general manager and a director of Hotpoint Inc. He succeeds **James J. Nance,** who resigned to become president of Packard Motor Co. Mr. Sharp has received national recognition as a result of several major appliance designs developed at Hotpoint under his direction.

♦

Ernest F. Miller, steam division engineer of the Westinghouse Electric Corp., Pittsburgh, has been awarded special recognition, as well as a check for $5000, for his invention of a gas turbine combustor that made possible the successful long-life operation of the first all-American jet engine. Mr. Miller's invention resulted in a combustor made up of telescopic circular sections that allow relatively cool air to pour over the inner surface of the combustor wall, cooling it and eliminating the damaging hot spots encountered in previous designs.

♦

Previously manager of the newly created manufacturing engineering section, **John A. McGown** has been named manager of quality, standards and manufacturing engineering for the X-Ray department of General Electric Co. at Milwaukee.

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. . . to your direct current motor problems, look to your nearby Fairbanks-Morse Electric Motor Specialist.

He is technically qualified to help you select the equipment exactly suited to your D.C. needs.

Whether you are interested in a D.C. or A.C. motor . . . one or a thousand—one type and size, or a variety of types and sizes . . . you'll find that motors carrying the Fairbanks-Morse Seal are designed and built to your most rigid requirements.

When you look for electric motors—for standard or unusual applications—*always* look for the Fairbanks-Morse Seal. For over 120 years it has stood for the finest in manufacturing integrity to *all* industry. Fairbanks, Morse & Co., Chicago 5, Illinois.

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a name worth remembering when you want the best

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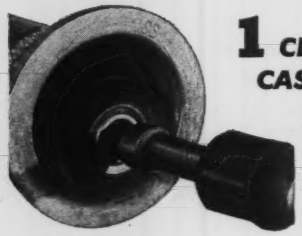
Pittsburgh Brushes Solved these Problems!

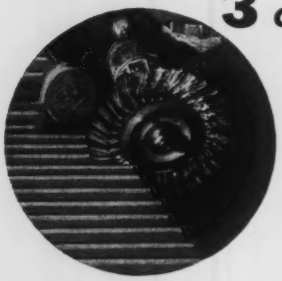


1 CLEANING RED-HOT CASTINGS in 30 seconds!

A Pittsburgh brush answered U. S. Pipe and Foundry's problem of cleaning red-hot castings. This rugged brush works 40 hours a week, turning out thoroughly cleaned castings at the rate of one every 30 seconds . . . a speed record for any brush cleaning operation of this type.

2 POLISHING 10,000 heating units!

When the Edwin L. Wiegand Company wanted to remove ragged edges from their *Chromalox* Heating Units economically and *fast*, they turned to rough, tough Pittsburgh Brushes for the answer. The 6" Pittsburgh steel wire brushes they installed polish 10,000 heating units during their life.



3 CLEANING WELDS in close quarters!

Allis-Chalmers' problem was to find a brush narrow enough to fit between cooling fins of transformer radiators, yet strong enough to remove slag and spall on welds which could conceal pressure-reducing pinholes. Pittsburgh engineers recommended an 8" rotary wire brush. Problem was solved!

Let Pittsburgh Engineers Solve Your Brush Problems.

Pittsburgh's complete line of brushes of every type, for every purpose, will provide a practical and economical solution of any brush problem you might have. Drop us a line on your company letterhead for a copy of our new booklet that shows, through actual case histories, how Pittsburgh can help cut your brushing operation costs. Address: PITTSBURGH PLATE GLASS COMPANY, *Brush Div.*, Dept. W-1, 3221 Frederick Ave., Baltimore 29, Maryland.

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THE ENGINEER'S Library

Industrial Heat Transfer

By F. W. Hutchinson, professor of mechanical engineering, University of California; published by The Industrial Press, New York; 336 *pages,* 6 *by* 9 *inches, clothbound; available from* MACHINE DESIGN, $6.00 *postpaid.*

Graphical equation solutions and a unique arrangement of subject matter are features of this book which deals with industrial heat transfer analysis. A selective approach to subject matter has been used with discussion centering around equations having widest industrial application. Text material has been kept brief and over two-thirds of the content is devoted to simplified graphical evaluations of the complex heat transfer equations. The material arrangement has been designed to provide the practicing engineer with a working handbook and the student with a practical textbook.

After opening with a brief introductory chapter on general heat transfer analysis principles, the book takes up in turn: Conduction, radiation, basic convection relationships, combined heat transfer, and forced convection. Graphical solutions, self-contained and independent of the text, are provided at the end of each chapter for major equations presented in the chapter. The accuracy of these graphs equals that of the equations. Each page facing a graphical solution contains an explanatory title, a statement of the equation solved, a summary of limitations and extensions, and a numerical example in the use of the graph. In some instances, cross-references to text material have been provided.

New Standards

*Wrought-Copper and Wrought-Bronze Solder-Joint Fittings—ASA B*16.22-1951: Seamless fittings designed for use with copper water tube are the subject of this seven page standard. Items covered are: pressure ratings; abbreviations for end connections; size, and method of designating openings of reducing fittings; marking; minimum requirements for material; dimensions and tolerances; and tests. The last page of the standard is devoted to sketches showing the method of designating laying lengths of fittings and openings of reducing-fittings. Copies of the standard are available for 75 cents each from the American Society of Mechanical Engineers, 29 W. 39th St., New York 18, N. Y.

Malleable-Iron Screwed Fittings, 150 *lb—ASA B*16.3-1951: Changes incorporated in this new stand-

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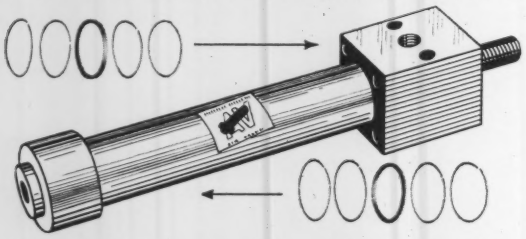

Heavy duty Airmatic cylinders, made by Airmatic Valves, Inc., Cleveland, and widely used in the aircraft and other industries, now use PALMETTO G-T Rings in place of conventional type packings.

By employing G-T Rings—which require only a rod and piston groove—Airmatic has been able to simplify cylinder design; eliminate complicated stuffing boxes, back-up plates and hold-in bolts. As a result, manufacturing costs have been drastically reduced.

And, because G-T Rings—unlike conventional Rings—cannot roll in the groove under high pressure, spiralling and extrusion of packing is no problem . . . smooth, efficient performance is assured with minimum servicing of packing. Heavy duty Airmatics, with 1" bore cylinders, operate at pressures up to 1500 psi on oil or water—exert a force on the ram equal to 78% of the input. More than 5,000,000 trouble-free 3" strokes have been recorded on original Airmatic cylinders with PALMETTO G-T Rings.

HOW PALMETTO G-T RINGS WORK . . .

Fig. 1 shows Palmetto G-T Rings with no pressure applied. CLEARANCES between the FLANGES of the RESILIENT SECTION and the laminated plastic NON-EXTRUSION RINGS, as well as between rings and CYLINDER WALL prevent low pressure friction.

Fig. 2 indicates how the RESILIENT SECTION flows under pressure, causing the FLANGE to swell under the rings on the low pressure side, bringing them to bear on the CYLINDER WALL. CLEARANCE spaces are closed, preventing any extrusion of the packing material. The piston, forced to a central position, will move forward without binding or jamming and with no damage to packing or CYLINDER WALL. Elimination of extrusion of the packing material is the outstanding feature that makes Palmetto G-T Ring Packing the ultimate in seals.

If a better packing will better the product you make, count on Greene, Tweed to lend assistance. Write for literature that describes all PALMETTO Packings.

packing more performance into every application

PALMETTO Packings

GREENE, TWEED & CO. NORTH WALES, PA.

ard include: amplification of the section on threading; addition of inspection tolerances on fitting dimensions; additional sizes to tables covering elbows and crosses (reducing sizes), tees (reducing sizes), couplings (straight and reducing sizes), caps, and return bends. Copies of this 14 page standard which supersedes American Standard *B* 16*c*-1939 are available for $1.00 each from the American Society of Mechanical Engineers.

ASTM Standards on Copper and Copper Alloys: Standard and tentative specifications and test methods pertaining to copper and copper-base alloy products are the subject of this 520-page book published by the American Society for Testing Materials. Items covered are: plate, sheet, rolled bar and strip; rod, bar and shapes; pipes and tubes; wire; sand and die castings; arc-welding electrodes and brazing solder; standard nominal diameters and cross-sectional areas of American Wire Gage sizes of solid round wires; stranded conductors and other electrical usages of copper. Specifications are also included for some nonferrous metals such as slab zinc, pig lead, nickel, phosphor, silicon, electrolytic cathode copper, and others, Available from the American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa., copies are $4.75 each with heavy paper cover or $5.40 each with cloth cover.

1951 *Supplements to ASTM Standards*: These supplements to the 1949 Book of ASTM Standards cover some 299 specifications, tests and definitions which were either issued for the first time in 1951 or were revised since their appearance in the 1949 Book or the 1950 Supplements. Issued in six parts, the new supplements consist of:

Part 1—*Ferrous Metals:* 54 standards, 416 pages

Part 2—*Non-Ferrous Metals:* 75 standards, 360 pages

Part 3—*Cement, Concrete, Ceramics, Thermal Insulation, Road Materials, Waterproofing, Soils:* 50 standards, 280 pages

Part 4—*Paint, Naval Stores, Wood, Adhesives, Paper, Shipping Containers:* 46 standards, 264 pages

Part 5—*Textiles, Soaps, Fuels, Petroleum, Aromatic Hydrocarbons, Antifreezes, Water:* 41 standards, 344 pages

Part 6—*Electrical Insulation, Plastics, Rubber:* 33 standards, 248 pages.

Copies of the supplements, in heavy paper cover, can be obtained for $3.50 per part or $21.00 for the set from American Society for Testing Materials.

Equivalent Valves: This 170-page loose-leaf manual compares valves of eighteen manufacturers by material, type, pressure rating and structural variations. Over 50,000 postings of figures, names and descriptions, including cast iron and bronze valves, are furnished in this book which has been compiled for those who must specify valves or check on the specifications of others. The manuals are $25.00 each —annual revision service is available. Copies can be obtained from Equivalent Valves Co., P. O. Box 816, Station H, Los Angeles 44, Calif.

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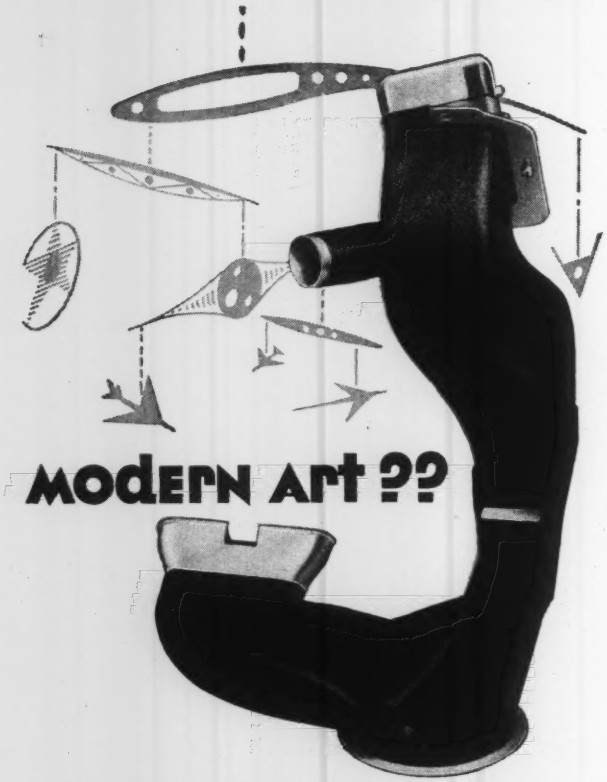


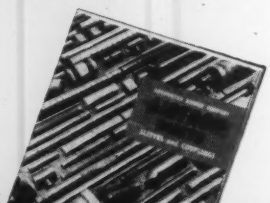
YES, IT'S MODERN ENGINEERING ART—

the art of fabricating Fiberglass ducts in shapes too complex for conventional materials. Arrowhead Rubber Company's custom-built Airtron ducting, made of flexible rubber impregnated Fiberglass, offers many advantages over metal. Ducts designed to individual customer specification can be made to practically any conceivable shape in experimental or production quantities at cost savings frequently as much as 45%. Tooling costs are reduced to a fraction—as compared with metal. Costly metal forming, riveting, welding and sealing are eliminated.

Airtron ducts offer other unique features. Weight savings up to 50% are possible. Flexibility allows crushing without damage and easier installation. They are self-insulating, immune to vibration and corrosion, can be made to close tolerances with metal fittings, flanges and other features built in.

The Airtron duct shown above solved a cramped space problem encountered in the design of a heavy bomber. It's typical of countless unusual ducting problems which Arrowhead engineers specialize in solving.

WRITE FOR CATALOG
on Airtron and name of nearest sales engineer.
Dept. A-40



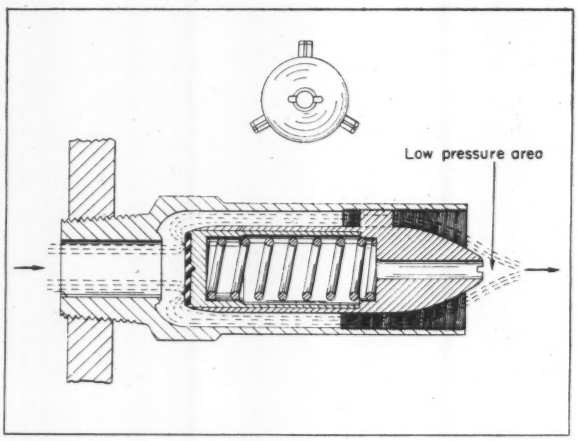
"O" RINGS
AIRTRON DUCTS
ARCOSIL SILICONE RUBBER PRODUCTS

ARROWHEAD RUBBER COMPANY
Division of National Motor Bearing Company, Inc.

DOWNEY, CALIFORNIA (Los Angeles County)
FIRST commercial manufacturers of precision "O" rings; PIONEER fabricators of silicone rubber; ORIGINATORS of rubber-fiberglass ducting.

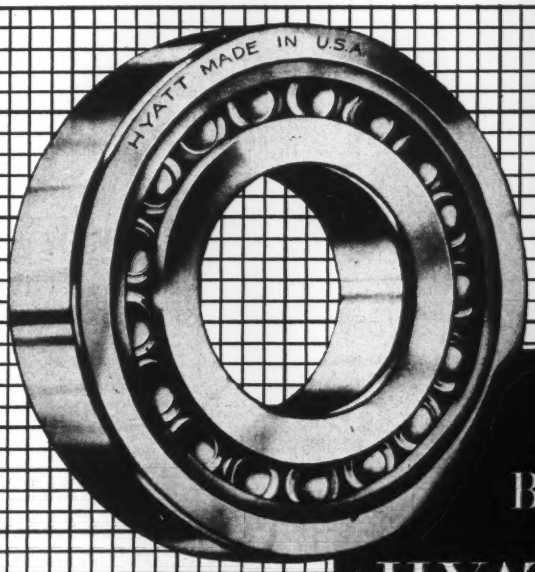
NOTEWORTHY Patents

PROJECTILE-SHAPED GUIDE SLEEVE in a gaseous fluid poppet relief valve minimizes stream turbulence and produces laminar flow through the passageway. This permits greater flow capacity in a given size valve because of reduced back pressure at the valve seat. Airfoil-shaped projections with threaded tips support the guide sleeve centrally in the valve body and provide for pressure adjustment.



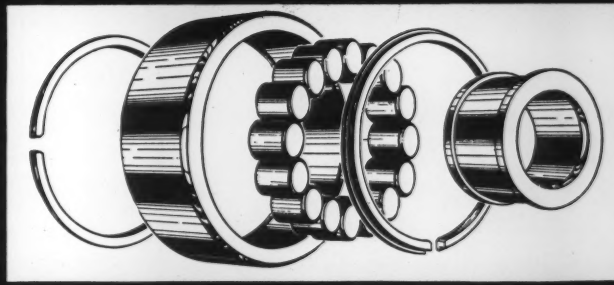
Downstream end of the sleeve is contoured to induce a low-pressure area at the tip during discharge. The valve spring chamber is vented through the sleeve tip into the low-pressure area to reduce the normal discharge pressure against the spring end of the valve. This prevents objectionable chatter or valve flutter usually resulting from discharge pressure buildup on the spring end. Patent 2,577,851 assigned to the Weatherhead Co. by Frank Hribar.

TANDEM DIAPHRAGMS balance fluid pressures in a poppet-type pump regulator valve designed for maintaining a constant discharge pressure differential above a base pressure even though the base pressure may fluctuate. The valve is guided in sliding movement by a stationary pilot rod within an accurately centered hole in the stem portion of the valve. Flow through the valve takes place only in passages located between the diaphragms, this construction eliminating fluid loss outside the flow circuit. Pressure differential regulation is accomplished by adjustment of counteracting compression springs at both ends of the valve stem. Base pressure, or control pressure, is maintained on the control side of the "operating" diaphragm, while the control side of the other dia-



For Maximum Bearing Capacity

HYATT HY-LOADS



THE U-TM type of Hyatt Hy-Load Roller Bearing is non-separable, the rollers and both races being assembled as a complete unit. For maximum bearing load capacity there is no separator or cage to space the rollers, thereby permitting a greater number of rollers to be assembled in the annular space between the races.

Bearings of this type are known as full complement bearings. Hy-Load full complement bearings are designed with close circumferential clearance assuring positive roller guidance and quiet operation.

The non-separable types of Hyatt Hy-Loads, such as the U-TM, are made for applications where the bearing must be assembled as a complete unit and where capacity greater than that obtainable in an equivalent separator type is desired.

★ ★ ★

Full information about the U-TM and other Hyatt Hy-Load Roller Bearings is "yours for the asking" in Hyatt catalog 547. Write for your copy to Hyatt Bearings Division, General Motors Corporation, Harrison, New Jersey.

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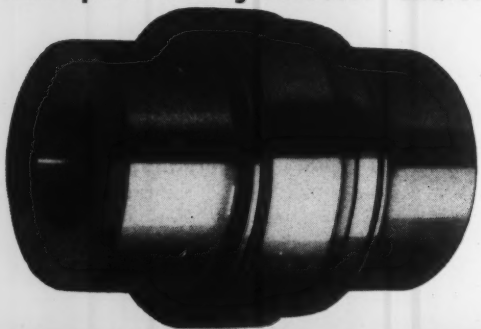

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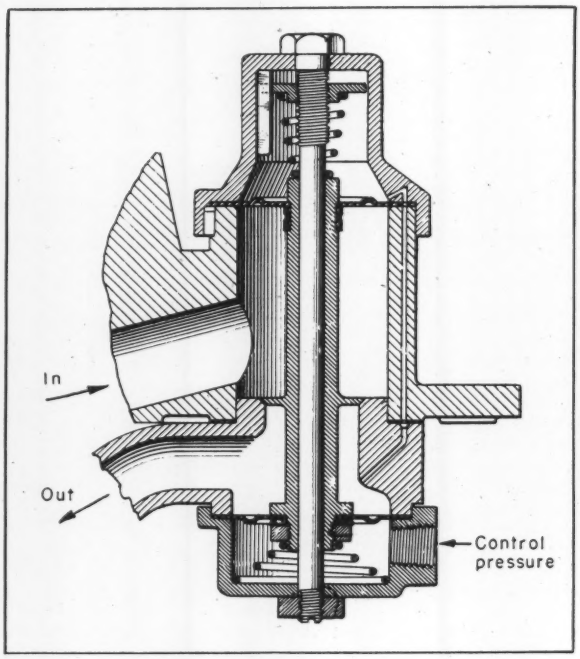
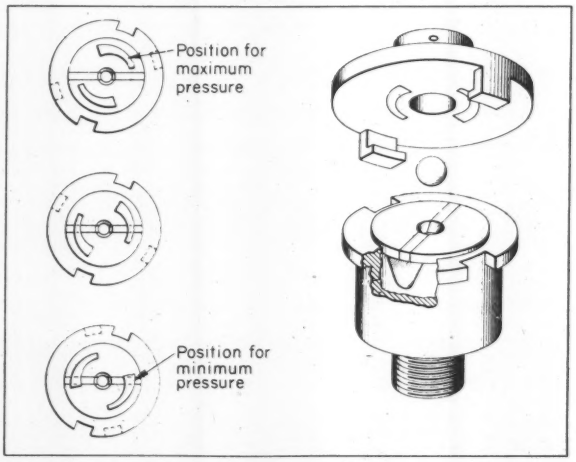
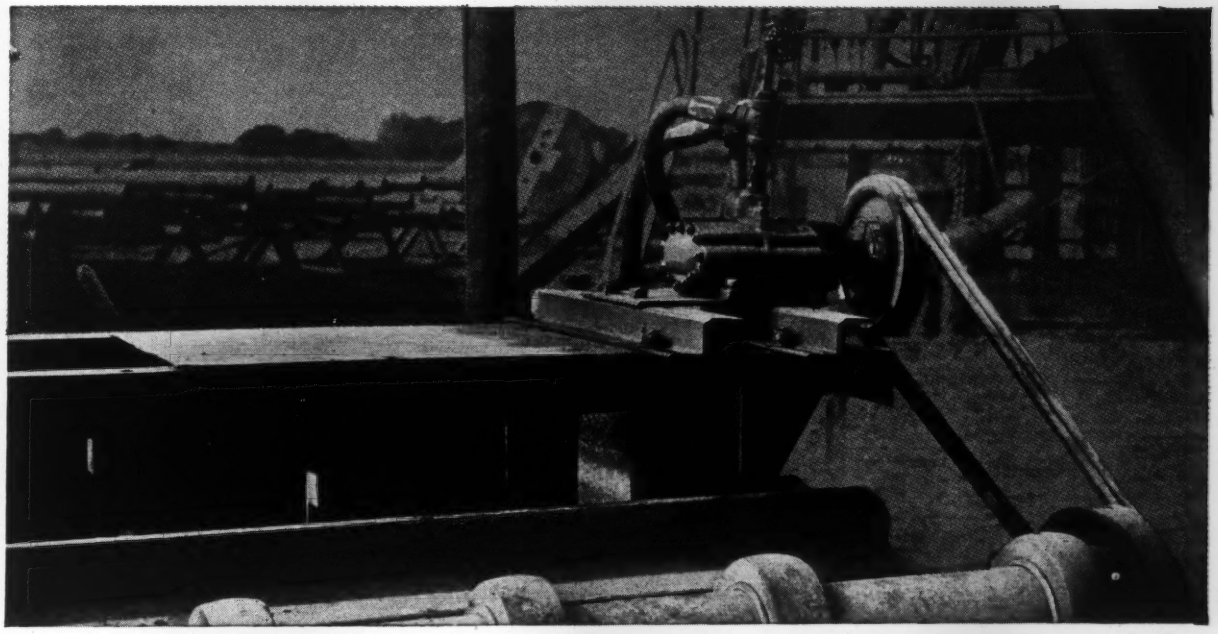


phragm is exposed to flow input pressure through drilled passageways in the valve body to counterbalance pressure exerted on the valve area. If the control or base pressure drops, the regulator valve responds by closing the poppet valve sufficiently to maintain the pre-established pressure differential in the flow circuit, or vice versa. Patent 2,563,138 assigned to Thompson Products Inc. by Frederick E. Smith.

CURVED TAPERED STEEL INSERTS in the nonmagnetic cap of a magnetic ball relief valve enable infinite adjustment of the discharge pressure from minimum to maximum through simple rotative positioning of the cap. Through segmental pole-pieces of a built-up valve disk, coercive force of a pressed-in tubular Alnico magnet attracts the ball to a conical





NEW hydraulic transmission sets record endurance mark!

Powering a vibrating screen on an oil well drilling location in Oklahoma, a single place 1400 series Berry fluid motor recently withstood vibration of 2200 cycles per minute, for over 20,000 continuous hours.

At the end of that period, the Berry unit had merely lost some efficiency from normal wear. Because of the simplicity of its design, the Berry hydraulic motor survived visible vibration where every previous installation had failed.

Belt-driven from the power take-off of the main oil well power rig, a single place 1400 series Berry pump furnished oil under pressure to the Berry motor—100 feet away—through hydraulic lines. The motor agitated the vibrating screen by means of an eccentric, thus creating the necessary vibration which the motor itself had to withstand.

The ability of the Berry motor to shrug off intense vibration testifies to its rugged qualities — qualities that make for economy, ease of maintenance and long life in *any* application.

If you have a power transmission problem, investigate the Berry solution—a modern, simple solution that is proving itself in installations such as auxiliary drives on trucks and trailers; portable conveyors; coil winding lathes; wire coating machines; forging hammers — wherever there is an unusual job requiring utmost stamina with minimum attention. Write us for full details of Berry hydraulic pumps and motors.

5 reasons
why Berry may be the answer to *your* power problem

- **Minimum loss of power through friction is obtained through use of free-floating rotating parts, plus rolling contact between high and low pressure areas.**
- **Instantaneous reversibility under load is possible because of the simplicity and symmetry of design and the small inertia mass in the rotating parts.**
- **High shock load capacity is achieved through generous design of component parts, plus monolithic mass of "stacked" plates. Sturdy piston design eliminates breakage, distortion or shearing.**
- **High starting torque is an outstanding characteristic since the unbalanced piston design forces rotation.**
- **Uninterrupted flow of power results in pulsationless smoothness of operation through the single-pass sweeping fluid channel, as interacting pistons push the liquid in a continuous manner.**

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OLIVER IRON AND STEEL CORPORATION
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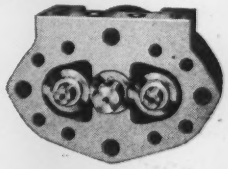

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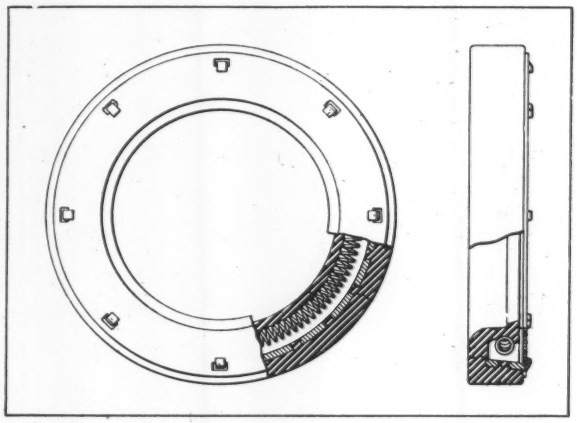
seat in the center of the disk. Brazed nonmagnetic spacers which separate the pole-piece segments also form part of the ball seat. A permanent fixed "air gap" is established between the regulating inserts and the pole-pieces by a plated nonmagnetic coating on the top of the valve disk. At different angular positions of the cap, the tapered inserts shunt predetermined percentages of the magnetic flux from pole to pole, thus varying the effective pull on the valve ball. Patent 2,575,906 assigned to General Electric Co. by Robert O. Bullard.

FLOATING SEAL FLANGE provides positive spring retention and protection against dirt-fouling of the garter spring in a molded type shaft oil seal. The metal flange is held to the molded ring by a series of lugs integral with a conical section steel ring insert-molded in the seal. The lugs project through



loose-fitting rectangular holes in the flange and are bent over to clamp it in place. Within practical limits, radial flexibility of the seal is unaffected by the metal parts, thus permitting satisfactory assembly and service in nonprecision rough-bored housings. Patent 2,565,190 assigned to the General Tire and Rubber Co. by Thomas H. Winkeljohn.

PNEUMATIC CUSHION between a dead weight and the diaphragm of a pressure-relief valve provides a "dead tight" seal at the valve seat in that it exerts equal sealing pressure on the diaphragm at all points around the seat. Air or gas entering the valve passes through a central hole in the ring-clamped diaphragm and tends to separate the weight and the diaphragm, thus forming the cushion. Effective area controlling the relief pressure is the cushioned area of the weight instead of the usual discharge orifice area only. Difference in opening and closing pressures is controlled by restricting the escape of air from the exhaust chamber, thus pressurizing a still greater lift area under the weighted diaphragm. During discharge a static air cushion is maintained between the dia-

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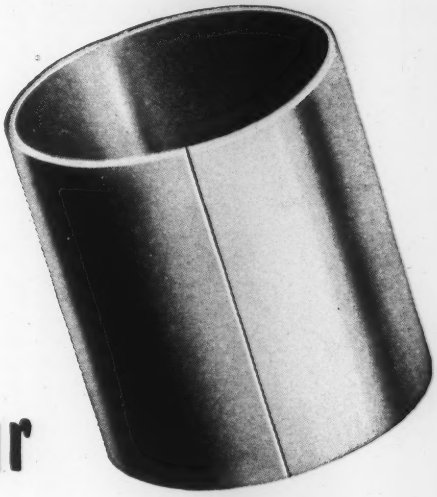

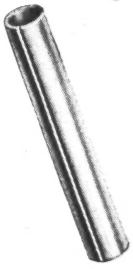

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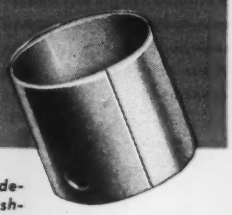

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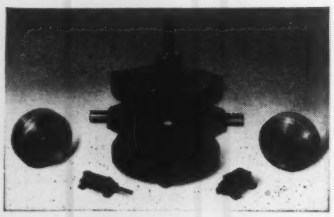

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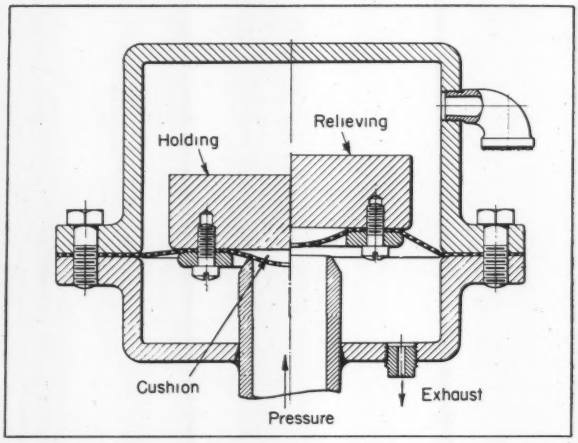
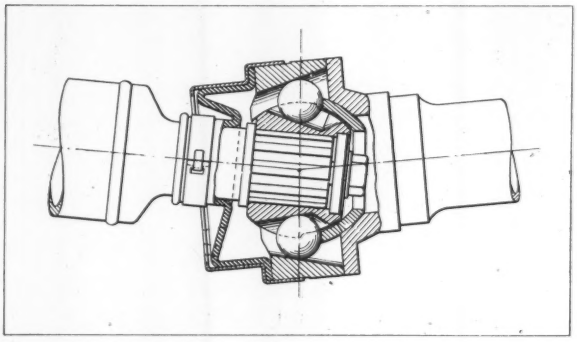


phragm and weight by orifice jet action. This avoids pinching the diaphragm and enables the forming of a full seal immediately when the valve closes. Patent 2,576,517 assigned to Shand and Jurs Co. by Peter C. Jurs.

STRAIGHT BALL RACEWAYS in a constant-velocity universal joint obviate numerous manufacturing handicaps involved in the manufacture of previous ball-type joints. Expensive contour grinding is eliminated, and a minimum number of fairly simple parts comprise the new joint. Mating grooves of the driving and driven members are tapered reversely,



permitting an open-end ball retainer or cage to be used. Through the shell-like retainer, rotative plane of the balls is established midway between the shaft axes without binding or cramping action. A flexible boot lubricant seal is required at one end of the joint only, and the unit may be assembled or disassembled readily without special tools. Patent 2,579,356 assigned to Borg-Warner Corp. by Edmund B. Anderson.

D-SHAPED CAM in a precision limit switch provides wide overtravel range by permitting full 180-degree movement of the actuating roller arm. In neutral or free position of the arm, contact clearance in the switch may be as little as a few thousandths

This king pin — pivot between the power unit and scraper of a heavy-duty, self-propelled, earth-moving machine — was formerly produced as a forging-weldment combination.

Conversion to a steel casting reduced the weight from 1100 lbs. to 850 lbs., provided strength equal to the strength of the more massive forging, and reduced production time by eliminating more than forty hours of welding.

* * *

Here is another example of the engineering teamwork in design and redesign of parts which is resulting in greater serviceability and lower costs with steel castings.

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CONVAIR P5Y Uses NEW LORD TURBO MOUNTINGS

To Isolate Vibration of 22,000 Shaft Horsepower

This is the world's first turboprop water-based aircraft (U.S. Navy) flying over San Diego bay. The vibration of 22,000 Shaft Horsepower, the contra-rotating propellers and the gear boxes is isolated from the airframe through the use of 6 Lord Mountings on each of the 4 gear boxes.

Each of the 4 dual engines is also Lord Mounted.

The Navy's new P5Y water-based aircraft is used for long range search-rescue and anti-submarine patrol missions. The world's first turboprop water-based aircraft is equipped with the world's first Lord turbo power plant mounting . . . a typical example of the manner in which Lord experience and research serves manufacturers of aircraft. Lord Engineering capabilities team up with precision manufacture to protect aircraft, to lengthen engine life, to increase crew comfort and alertness by isolating destructive vibration and shock. Regardless of the industry in which you are battling with vibration and shock, it will pay you to call in Lord Engineers.

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HEADQUARTERS FOR VIBRATION CONTROL

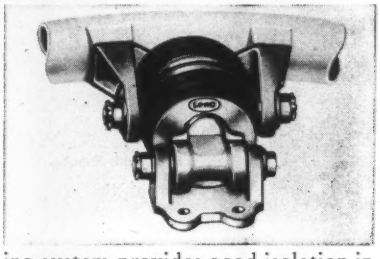
Lord Engineering Design Solves Unique Dual Vibration Problem in Mounting 22,000 Horsepower

Two distinct vibration isolation problems were present in mounting the 4 Allison remote-coupled T40 Turboprop Power Plants used in the Convair P5Y.

First, the vibration set up by the 14,300 r.p.m. of the turbine engine required a mounting system which would isolate first order engine disturbances. This was done using a stable mounting system with relatively small deflections for the power section alone.

Second, the operation of the propeller at 870 r.p.m. required a relatively soft, large deflection, mounting system for proper isolation of the remote gear box. However, the permissable misalignment of the flexible shafting from the power section to the gear box restricted mounting motions to narrow limits.

The problem was solved by using a soft, Lord Dynafocal type mounting system in conjunction with a torque restraining device. The mounting system provides good isolation in the vertical, lateral, pitch and yaw modes. In the roll direction, the torque restrainer holds the gear box from moving under torque loads. Thus critical vibration is isolated and gear box motions held within tolerance.



In addition, the mounting system provides positive snubbing, preventing the gear box from deflecting beyond the shaft input misalignment limits under transient overloads.

Thus, in brief, the analysis and subsequent attack of this unusual dual vibration problem by Lord Engineers provided the required isolation where extremes of vibration frequency and motion were encountered.

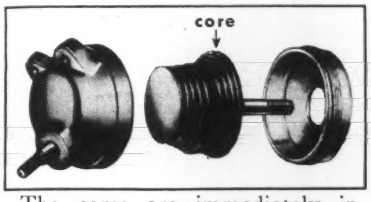
Further details on this and other difficult vibration isolation problems are available to those who write to Lord Manufacturing Company, Erie, Pa.

Advertisement

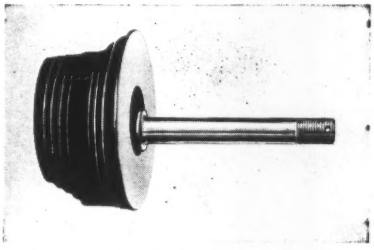
Lord Core Renewal Service Reduces Engine Maintenance Costs

Consistent with good airline maintenance practice, the Lord Manufacturing Company, Erie, Pa. has instituted a core renewal service on Lord Dynafocal Suspensions which is effecting material savings for airlines.

This service enables airline maintenance men to remove used cores from engine mountings, replace them with the stocked spares and return the old cores to the Lord factory.



The cores are immediately inspected, classified and checked by the Lord inspection department where the old rubber is removed and the metal is thoroughly cleaned. The metal parts are carefully inspected a second time to be sure they are in perfect condition. Then new rubber is bonded to the metal parts, resulting in the equivalent of brand new cores. They are then returned to the airline maintenance depot for replacement stock.



The result of this Lord service is a material saving in parts and in replacement time. Stocking sufficient numbers of spare cores promotes prompt replacement when required —but renewal of rubber in old cores saves sizeable amounts on the overall maintenance budget.

The Airlines welcome this field proved procedure of renewing cores. Old parts are returned and credit applied to the cost of the rebonded core, thus substantially lowering mounting maintenance costs.

Further details are available to interested airlines by writing Lord Manufacturing Company, Erie, Pa.

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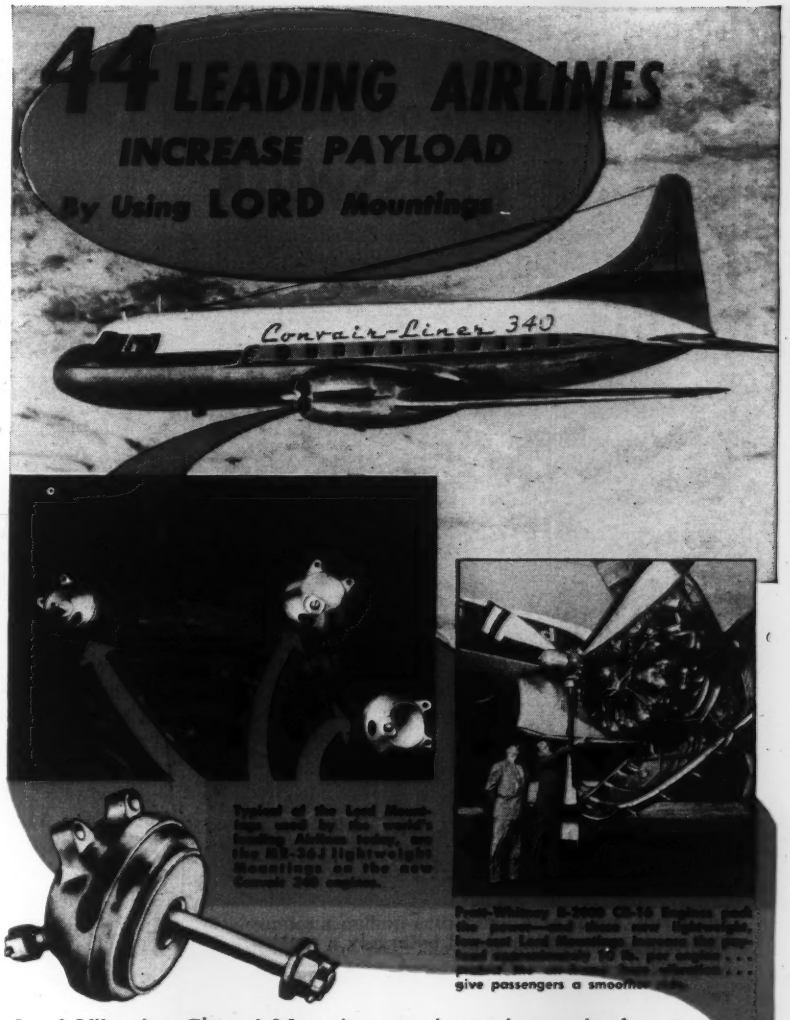

Lord Vibration Control Mountings are increasing payloads, protecting airframes, instruments and accessory equipment . . . adding to the comfort of passengers on 44 of the World's Leading Airlines. Why? Because Lord Engineering experience and manufacturing capabilities are providing light weight, low-cost mountings which contribute much to profitable airline operation. Lord engineering capabilities are being used to advantage by design engineers throughout world industry in their battle to isolate vibration and shock in a wide diversity of machines. Consult with Lord Engineers even before design takes shape on the board . . . and in perfecting machines already operating . . . You will profit.

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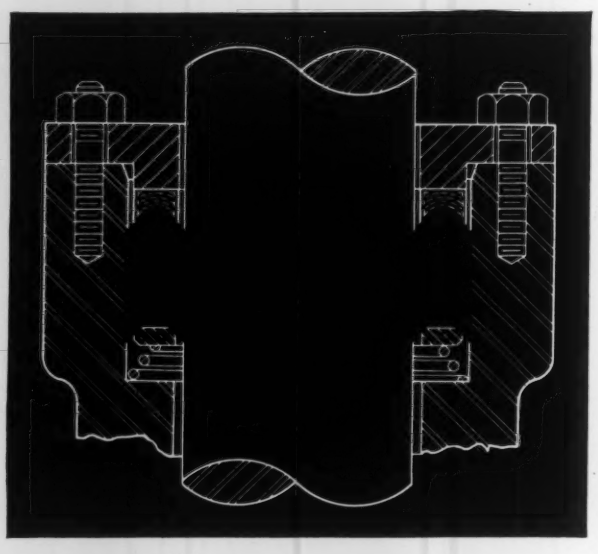
Why not eliminate guesswork entirely?



Tightening a packing gland is largely a matter of guesswork. *Over-tighten*, and you promote rapid wear and increase frictional drag. *Under-tighten*, and you risk joint separation of the rings and promote costly leakage.

To overcome this, many designers are specifying spring loading—a practice highly recommended by the J. I. C. Standards for Hydraulic Packings.

Spring loading with LINEAR "V" rings automatically provides the correct adjustment. Non-adjustable packing glands insure lower break-out and running friction. This means longer, trouble-free packing life all adding up to generous savings in reduced maintenance, down-time and replacement costs.

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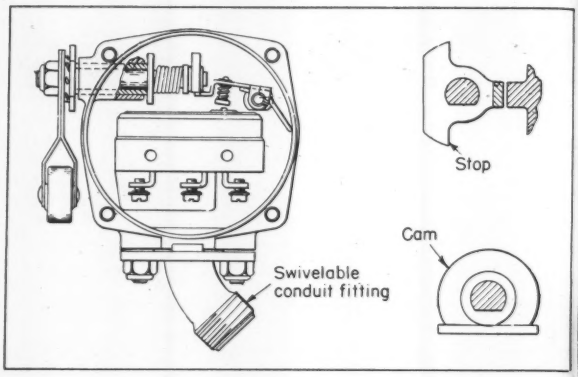
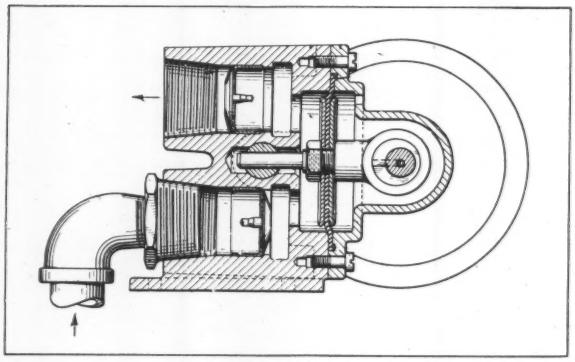


of an inch. Although only slight movement is required to close the spring-cushioned contacts, the arm may be operated through 90 degrees in either direction to a positive stop arrangement without detriment to the contact or mechanism. A torsion spring on the armshaft resets the switch to neutral position when the operating force is removed. Angular position of the arm is adjustable infinitely relative to the cam and is maintained securely by a star lockwasher clamped between the arm and a driving washer keyed to the shaft. Patent 2,573,833 assigned to Minneapolis-Honeywell by Carlo M. Christensen.

OSCILLATING DIAPHRAGM MOTION produced by a guided eccentric-driven connecting rod enables the use of relatively thin diaphragm material and is said to avoid twisting and chafing of the diaphragm in a lightweight fluid pump. Positive pumping action is thus assured and the usual diaphragm return spring is eliminated. Check valve assemblies in the pump also are springless, consisting of a press-fit perforated

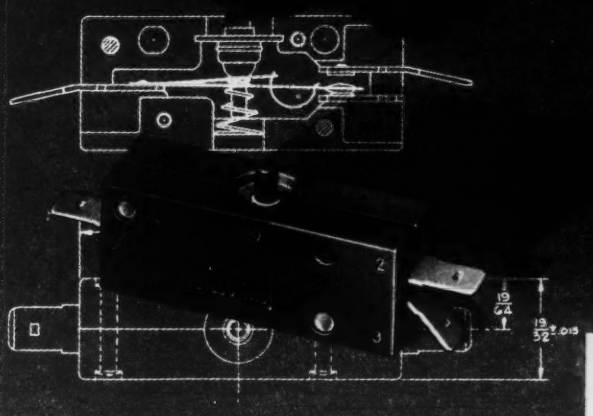


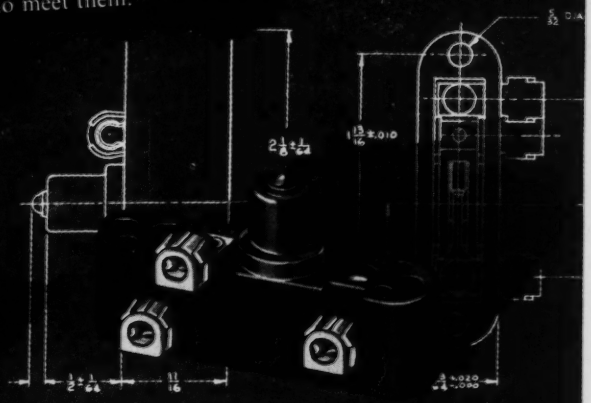
cup seat having a truncated cone rubber valve disk retained thereto by a molded stem pulled through a center hole in the cup bottom. Pressure differential causes the disks to dish outward from the cups, rather than to lift bodily, permitting one-way flow. Oil holes drilled in the eccentric shaft conduct lubricant from the shaft bearing reservoir to the eccentric. Patent 2,576,200 assigned to the Dayton Pump and Mfg. Co. by Robert Von Rotz.

SORENG

SWITCHES *to fit your* SPECIFICATIONS

What do your switch specifications require? Long life with millions of actuations? Dependable safety or interlock switch characteristics at a very low price? Perhaps mounting angle, size or ease of wiring are important to you. Whatever your particular requirements are, there is a Soreng Snap Action Switch to meet them.





Snap Action Switch—Type 13150

Adaptable for use as a limit, control, interlocking or safety switch, the 13150 is designed to give premium performance. If your application calls for millions of actuations during the switch life, you will find this switch capable *and* interestingly priced.

Electro-Mechanical Characteristics

- Single pole, double throw, normally open or normally closed.
- Single pole, single throw, normally open or normally closed.
- Rated 15a—125v a-c, 10a—250v a-c, ½hp—125/250v a-c.
- Soreng "Slide-on" terminals shown simplify and speed up wiring. Flush mounted, plug-in terminals also available.
- Switch may be bushing mounted or side mounted. For further data, drawings, etc., ask for Bulletin CF-118.

Snap Action Switch—Type 7990

Where cost is a prime factor and a switch life under a million actuations is adequate, this is the switch for you. The 7990 is excellent as an inexpensive safety, interlock or limit switch.

Electro-Mechanical Characteristics

- Single pole, double throw, normally open or normally closed.
- Single pole, single throw, normally open or normally closed.
- Rated 6a—125v a-c, 3a—250v a-c.
- Plug-in terminals shown. "Slide-on" terminals also available.
- Round head plunger may be cam actuated from any angle.
- May be vertically or horizontally base mounted. For further data, drawings, etc., ask for Bulletin CF-121.

Note: Engineering service is available to you for development of new switches or modification of present models to meet your exact requirements. For either of the bulletins listed or information on other electrical components, write Dept. C27.

Specialists in Electrical and Electronic Components.

SORENG MANUFACTURING CORPORATION

9555 Soreng Ave., Schiller Park, Ill. (Chicago Suburb)
Plants: Schiller Park, Ill. • Fremont, Ohio

for 50 to 1 reduction on
OZALID STREAMLINER
developer drives . . .

WINSMITH
SPEED REDUCERS
®

A copy in less than 30 seconds! Printing speed up to 14 ft. per minute! That's what this Ozalid Streamliner turns out for thousands of engineering, purchasing, personnel and accounting departments across the nation.

Because reproduction of letters, reports, drawings and records usually "can't wait", every component of Ozalid copying machines must be constantly relied upon to do its bit without failure. The Winsmith single reduction, 50:1 ratio, right angle drive, worm gear type reducer is a good example.

Serving the blower, developer and pump drive, which is powered by a 1/3 hp motor, this small, compact Winsmith unit is designed for the long-lasting service which Ozalid requires of all its components. Moreover, its vibrationless operation is necessary to the smooth, quiet performance for which the Streamliner is so well known. "We are pleased with the little servicing that these units have demanded over countless hours of usage", says Ozalid's chief engineer.

The importance that Ozalid, Division of General Aniline and Film Corporation, places on the selection of a speed reducer is typical of most industries . . . the very reason so many have become Winsmith users. Within the 1/100 to 85 hp range, no other speed reducer is available in so complete a selection of standardized types, sizes and ratings. *Catalog 148 will convince you.* Write!

WINSMITH, INC.
16 ELTON ST.,
SPRINGVILLE (Erie County), N.Y.

Stress Relief

CHARACTERS he's known are not J. P. Henderson's sole targets in his series of critical monographs. Here he takes off on a somewhat different idea.

People are Important

Do you carry an address book in your pocket, with important telephone numbers carefully inscribed? If so, you have the elements of a good idea that should be expanded.

Perhaps we are not thinking of the same thing. I am referring to the fact that to you as an engineer, the names, addresses, and job listings of various people you have met can be an extremely valuable asset.

You have just received a minor promotion. Those three men you've been working with for five years are working for you now. You have hardly gotten over feeling smug about it before the big boss comes around with news:

"As you know, we're expanding these activities and will have to hire someone for your group. You can use the regular employment service, but I thought you might have someone in mind who would be especially suitable, and whom you might want to hire. Think it over and let me know."

That's fine, you think. Let's see. Just last month you were impressed by that chap you met at the engineers' club dinner. Been doing work right along your line. You gathered from his talk he could be moved. What was his name? Calkins? Colvin? No?

Well, what did he say was the name of his company? Ruefully you decide you can't remember that either. All right, who was that chap you saw last summer, who told you outright he was looking for a new connection? Bob Harrison. Right. But what company did he say he was with? Some outfit in Chicago.

Continued mental exploration

FOR PRINTED OR ETCHED CIRCUITS

now available!

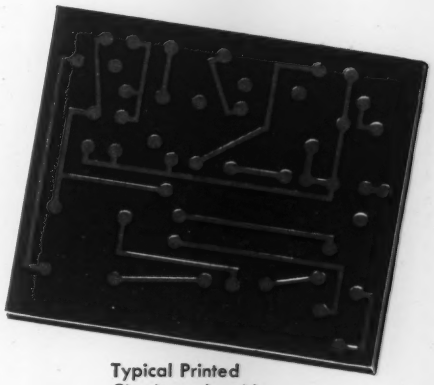
metal-clad INSUROK T-725 and T-812 plastic laminates

Laminated INSUROK Grades T-725 and T-812 have made history ever since they were first introduced to the electronics industry. These laminates, possessing a unique combination of properties, have shown sensational performance in critical high-frequency applications.

Now these superior electrical laminates are available in *Metal-Clad* form (with copper or aluminum sheet bonded to one or both surfaces) for the production of "printed circuits."

Metal-Clad INSUROK exhibits outstanding electrical properties which remain remarkably stable under repeated temperature and humidity cycling. In addition, it possesses high physical strength and low cold flow, and punches readily into intricate shapes. The metal foil is bonded by a special process assuring consistently higher bond strengths than ever offered before.

Samples of Copper or Aluminum-Clad INSUROK are available for testing purposes. Send for complete information, today.



Typical Printed Circuit made with Metal-Clad INSUROK

The RICHARDSON COMPANY

FOUNDED 1858—LOCKLAND, OHIO

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HELI-COIL* INSERTS

These stainless steel wire inserts strengthen threads so greatly that stripping is eliminated, thereby allowing you to utilize the full tensile strength of each cap screw. You can: (A) *use smaller cap screws* — (B) *use fewer cap screws* — (C) *use shorter thread engagement* — (D) *use cap screws in place of studs or bolt-and-nut assemblies* — (E) *use lighter bosses and flanges.*

Inexpensive ***Heli-Coil*** wire inserts, easily wound into slightly oversize tapped holes, remain permanently in place, providing easy-running female threads that are immune to wear, galling and corrosion.

The result is an improved product — cleaner looking, lighter, easier to service—frequently at reduced manufacturing cost.

Case histories, pointing up these benefits, are presented in ***Heli-Call***, our engineering periodical which is yours for the asking. Use the handy coupon to put your name on the subscription list.

*Reg. U. S. Pat. Off.

HELI-COIL CORPORATION

127 SHELTER ROCK LANE, DANBURY, CONN.

☐ Please send catalog, giving full engineering specifications

☐ Please send *Heli-Call*, a free case-history periodical

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still leaves you blank and you finally decide the employment service will have to supply your man.

You fell down on one of the first requests given you as a minor executive. This won't damn you. Presumably you *could* be a good executive and still forget even the names of some of the persons working for you. But you would be a far better one if you knew thousands of people *and how to get in touch with them.*

It has been my experience that the higher a man goes on the administrative and executive ladder, the more heavily he leans on his acquaintance with people. Not that you always need these people for employment possibilities. You need them for advice, too.

Suppose that you or your organization are faced with a special problem, far outside your normal activities. Fred Knox is just the man; give him a call and ask him what he does about this sort of thing. In five minutes, Fred Knox may have settled your problem or referred you to someone who could. Perhaps you hadn't seen him in several years. You might have to explain who you are and where you saw him last. But human nature being what it is, Knox will be flattered at *your* remembering *him,* and in the glow of that flattery, will help you.

This sort of thing goes on regularly, and the higher the level of position the more "confidential" the type of information that can be obtained. People are important! People can help you do a better job.

To any young man starting a career in industry, I would suggest: Keep a little black book. Jot down the name and affiliation of that salesman who called on you; the man you met at the engineering dinner, or talked to at the trade show. Over the years, this practice can increase your effectiveness.

And if you get well acquainted with the right people you might be able to buy things at wholesale prices!

—J. P. HENDERSON

Along this same broad vein, we recently stumbled into the middle of an exchange aroused by one

HYDRAULICS FOR MOBILE EQUIPMENT

VOL. 1

Mobile Equipment News

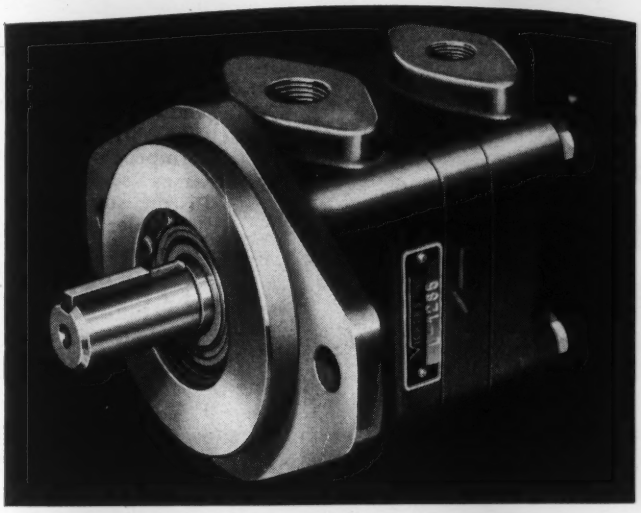
VICKERS INCORPORATED, DETROIT, MICHIGAN

IMPROVES PERFORMANCE • CUTS COSTS

NO. 1

NEW VICKERS SERIES V-100 PUMPS ADDED TO MOBILE EQUIPMENT LINE

Compact, efficient, rugged . . . this new and smaller addition rounds out the Vickers line of vane type pumps designed especially for mobile equipment. These pumps have established a reputation for doing a better job and lasting longer . . . at lower overall cost.



HYDRAULIC BALANCE MEANS LONGER PUMP LIFE

The two internal outlet ports are diametrically opposite each other. The same is true of the inlet ports. Thus equal and opposite thrust loads eliminate bearing loads due to pressure. Lighter bearing loads mean much longer bearing and pump life.

AUTOMATIC WEAR COMPENSATION MAINTAINS TOP PERFORMANCE THROUGHOUT PUMP LIFE

Radial compensation for wear is in the vanes. The vanes slide freely in the slots and are moved out into contact with the cam ring by centrifugal force . . . then held there by hydraulic pressure as it builds up. As normal wear occurs, the vanes just move further out in the slots to compensate. (Wear is minimized because all parts are lubricated by the oil under pressure.)

Axial compensation is by means of a pressure plate held to correct running clearance by pressure from the system. It automatically moves in to compensate as wear occurs.

Automatic compensation eliminates need for "run in"... efficiency is maximum the first time the pump is started. It also assures maximum delivery over a very long life, with none of the gradual falling off encountered where there is no wear compensation.

V-100 PUMPS AVAILABLE IN 3 CAPACITIES

The Series V-100 Pump is available in three capacities: 1.5, 2.5, and 4 gpm at 1200 RPM and 0 outlet pressure. This choice of three capacities with same exterior dimensions facilitates matching pump to the job.

Ask for Installation Drawing No. 152060.

GREATER MOUNTING ADAPTABILITY

Series V-100 Pumps are available in two mounting styles . . . flange (magneto type) and foot mounting. The pressure connection can be placed parallel, opposite to or at a right angle in either direction to the inlet by simply unbolting and rotating the pump head. Shaft drive is in either direction depending only on internal assembly.

NO-LOAD STARTING

At rest and normal starting speeds, the sliding vanes are retracted; only after engine fires do vanes expand and pumping begins.

OTHER VICKERS BALANCED VANE PUMPS FOR MOBILE EQUIPMENT

Series V-300 pump made in 4 delivery ratings—12 to 24 gpm.
Series V-200 pump made in 4 delivery ratings—2 to 11 gpm.
Series V-400 pump made in 2 delivery ratings—28 and 36 gpm.
Series V-900 pump in 2 delivery ratings—50 and 86 gpm.
4773

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ENGINEERS AND BUILDERS OF OIL HYDRAULIC EQUIPMENT SINCE 1921

New Flexible Sealing...

T-J AIR CYLINDER

Designed with revolutionary application of

Super-Cushion

It's *sealed with pressure*—a revolutionary T-J application of flexible sealing that insures positive cushion action combined with automatic valving action for fast return stroke . . . eliminates binding and sticking . . . operates with *low friction, minimum wear,* and *added power* due to higher efficiency.

More PLUS features! New type packing nut incorporates a piloted diameter, assuring perfect alignment. Improved rod packing increases sealing efficiency. Piston rod and internal cylinder tube surfaces are hard chrome plated—a standard practice with T-J for over 15 years.

Write for bulletin 252. The Tomkins - Johnson Co., Jackson, Mich.

1. Metallic rod scraper to protect rod bearing and packing from dirt and grit.
2. Wrench flats.
3. Self-adjusting chevron type packing.
4. Permanent type adaptor ring.
5. Hi-tensile tie rods.
6. Heavy duty, hard chrome plated rod.
7. Generous fillet reduces stress concentration.
8. "O" ring static seal.
9. T-J new flexible cushion seal insures positive cushion with automatic valve action for fast return stroke. (Patent applied for)
10. Fine cushion adjustment.
11. Heavy wall precision honed hard chrome plate.
12. Controlled packing compression with metal to metal contact.

36 YEARS' EXPERIENCE T-J

TOMKINS-JOHNSON

RIVITORS AIR AND HYDRAULIC CYLINDERS CUTTERS CLINCHORS

of our *They Say's.* Besides being a utilitarian device (for filling out a column at the end of an article) a *They Say* is a current quotation intended to provoke thought or discussion. Recently we quoted Fred T. Agthe, consulting engineer (processing), Allis-Chalmers:

"A current plan for the young engineer should, first of all, include all of the activities that are necessary to round out engineering training to develop the engineer professionally and to make full use of his latent talents. After the young engineer has established himself and is recognized as an engineer of attainment, only then should he begin to devote some of the time at his disposal to enter a larger field of community activities that is useful, constructive and compatible with his background and mental development."

Well, it did provoke one of our readers—

To the Editor:

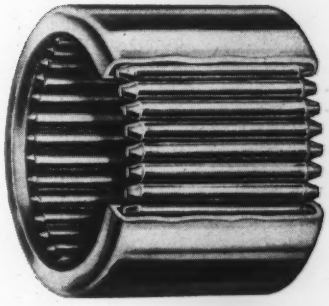
I don't know whether Mr. Agthe's remarks, quoted on page 150 of the May, 1952, issue of MACHINE DESIGN, were put there because the editors subscribe to the line of thought there expressed or because the remarks might stimulate discussion. At any rate, I have been thinking about them off and on for a week or so and I can't stand it any longer.

There can scarcely be any disagreement with the first sentence of the quotation, but the second sentence contains what to me are some horrendous implications. "After the young engineer has established himself and is recognized as an engineer of attainment, only then should he *begin* to devote *some* of the time at his disposal to enter a larger field of community activities. . . ." This would seem to imply, although Mr. Agthe may not intend so, that the young engineer should do nothing with his time but eat, sleep a little, and develop his latent talents until he is "recognized." When at last he is recognized by some board of examination, by promotion from his employer, or some other means, then he may attend Parent-Teacher meetings, help with the Boy Scouts, take an evening off to go to the township meeting to hear argu-

when high capacity pays off...

Torrington Needle Bearings are designed to handle heavy loads. A full complement of small diameter rollers distributes the load evenly over a large area. Thus—for a given O.D.—a Needle Bearing has greater rated radial load capacity than any other type of anti-friction bearing.

Other Needle Bearing advantages—compact size, light weight, ease of installation and maintenance—pay off, too. So let our engineers help you—as they have many others—take full advantage of Torrington Needle Bearings in *your* product.



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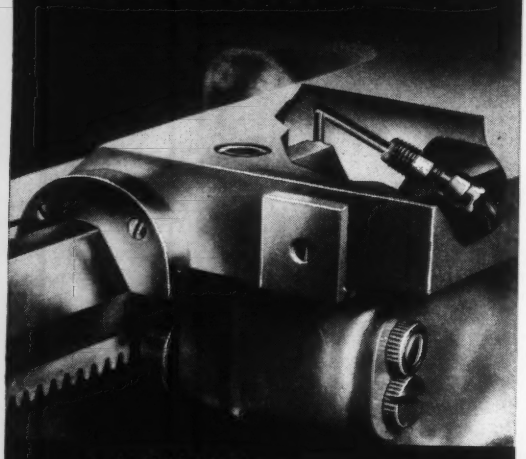
TORRINGTON *NEEDLE* **BEARINGS**

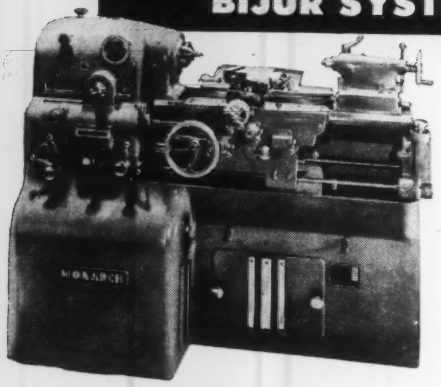
Needle • Spherical Roller • Tapered Roller • Straight Roller • Ball • Needle Rollers

How to **LUBRICATE A HORIZONTAL 'V' WAY**

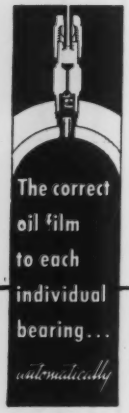


View thru the carriage of a small Monarch Toolmaker's Lathe showing drilled passage from meter-unit to bed way.

as MONARCH does it with a **BIJUR SYSTEM**



In this application, the problem was to maintain a film of oil between the carriage and bed way contact surfaces. It is solved by drilling thru the carriage to an outlet above the "V" way . . . controlling the oil flow thru a meter-unit at the drilled passage . . . supplying oil to this point from a built-in lubricator (actuated by a turn of the apron handwheel) which also oils the cross-slide dovetail and the apron bearings. This is another example of Bijur "teamwork for bearing protection." For aid in solving *your* lubrication problems, call in a Bijur engineer.



871

BIJUR

LUBRICATING CORPORATION

Rochelle Park , New Jersey

ments about expenditures for garbage disposal, or even allow himself to be drafted onto a committee for civic improvements, etc.

In other words, "*begin* to devote *some* of the time at his disposal" to be a member of his community and to live like a well-rounded, intelligent human being rather than a regimented imitation of a robot.

Perhaps one of the things wrong with this country is that it is being run by too many engineers who have waited until they have become "engineers of attainment" before finding out what is going on and doing something about it.

—GEO. STEYSKAL
chief designer
Standard Tool & Mfg. Co.

The quotation was taken from an ASME paper which contained many qualifications of this particular passage. For instance: "As maturity progresses, he [the young engineer] should offer his services to all of the worthwhile political and civic activities in which available time will permit him to engage."

Mr. Agthe, when apprised of the havoc wrought by our free use of his remarks, had this to say:

"The spirit of the address, a part of ASME's Junior Conference Program, was intended to evoke discussion among those present which I believe is appreciated by young engineers generally.

"It is my opinion that if Mr. Steyskal and I could sit down together to discuss his remarks, he would find that we are not too far apart in our opinions.

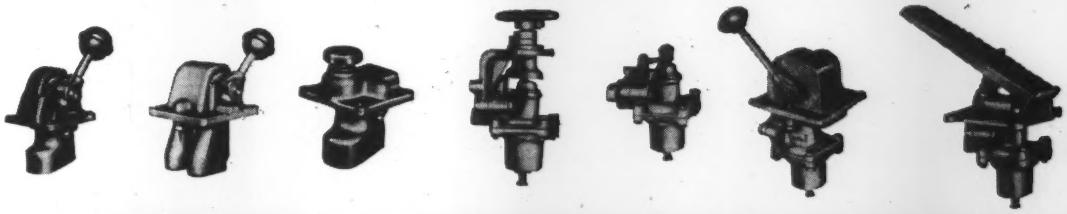
"In any event, if engineering aspires to be classified as one of the learned professions, I am of the opinion that the several years immediately after graduation should be spent in a whole-hearted training effort that will lead to professional development. After such a period of a year or two has been spent profitably, the young engineer will be better prepared to cope with civic responsibilities and to become a well-round citizen rather than 'a regimented imitation of a robot.' I deplore with Mr. Steyskal any robot trend in technical training and subsequent development which is inimical to civic and technological progress."

PRODUCTIVITY UP ...COSTS–DOWN

WITH THE NEW . . . COMPLETE LINE OF WESTINGHOUSE CUSHIONED PNEUMATIC CYLINDERS

1. DIAMETERS: 1½" to 8" . . . required stroke
2. CUSHIONED ADJUSTABLE STROKE
3. FLANGE, FOOT, SWIVEL, OR TRUNNION MOUNTING
4. PRESSURE TYPE END SEALS AGAINST LEAKAGE
5. ROTATING HEADS for EASY INSTALLATION
6. SOLID CONSTRUCTION— NO STAY BOLT STRETCH
7. STOCK HEADS, RODS AND BARRELS ASSEMBLE TO MEET REQUIREMENTS
8. PACKING CUPS OF FAMOUS "WABCO"® COMPOSITION

Combined with a complete range of modern pneumatic controls



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WESTINGHOUSE AIR BRAKE COMPANY WILMERDING, PENNA.

Factory Branch: EMERYVILLE, CALIF. Distributors throughout the United States . . . Consult your Classified Directory. Distributed in Canada by: Canadian Westinghouse Co., Ltd., Hamilton, Ontario.

V-1869

Preferred power on portable fire fighting pumps and floodlight electric plants — the world's most widely used single-cylinder gasoline engines on machines, tools, appliances used by municipalities, industry, construction, railroads, oil fields, and on equipment for farm and home.

The product of more than 32 years of air-cooled power experience — Briggs & Stratton single-cylinder, 4-cycle, air-cooled gasoline engines are preferred for every application demanding the most in dependable performance. Briggs & Stratton Corporation, Milwaukee 1, Wisconsin, U.S.A.

In the automotive field Briggs & Stratton is the recognized leader and world's largest producer of locks, keys and related equipment.

REPORT ON

Materials

INDUSTRY and government weathervanes seem to be pointing in every direction regarding the ending of materials controls. Some segments of the materials-producing industries are clamoring for decontrol actions in the near future, while others are content to remain quiet on the subject. NPA officials, while promptly decontrolling those materials in definite surplus, are also warning all and sundry about the dire effects of too rapid decontrol—and are therefore following a slow and cautious policy in initiating decontrol actions.

Many factors contribute to the confusion. Present conditions indicate an increasing supply except for certain short-supply materials such as nickel. But consumer demand for durable goods, labor unrest in certain metals-producing industries, and foreign prices and supply of minor metals could have a large impact on the progress of decontrol. Loss of steel production due to the steel strikes (an uncertain quantity at press date) could also change the decontrol picture.

Among the materials-producing industries which have joined steel in proposing definite decontrol plans for their products are prime aluminum products producers, the tin plate industry (for all secondary tin mill products), and the merchant pig iron industry. In contrast, nickel, copper, tin, and cobalt—all dependent to a greater or less extent on foreign imports—are still in very tight supply.

Relaxed and Revoked: Complete revocation of five materials orders covering four metals and substantial relaxation of a sixth were recently announced by NPA. The four metals which will become substantially free are lead, cadmium, bismuth and antimony. On zinc, the "relaxed" metal, allocation and use controls have been abolished, leaving only an inventory control.

In announcing the end of these

DARE TO COMPARE !

See the LIFE-LINESTARTER® STRIP-DOWN TEST for STEPPED-UP DESIGN

So simple you can disassemble it blindfolded.

The Simplest . . . Because of simplified design with fewer moving parts . . . because of easy installation with straight-through wiring and standard NEMA mounting.

The Toughest . . . Because of positive protection and rugged construction . . . patented De-ion® Arc Quencher—silver-to-silver contacts—Bi-metallic disc-type overload relay — Bonderized enclosure with baked, grey enamel finish.

Most Dependable Linestarter Ever Built! . . . A recent chemical-plant-test* showed: "Four starters began our life test. Only one finished, the Life-Linestarter. Contact wear was negligible." J-30097

**Name on Request.*

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Life-Linestarter

SEE THE STRIP-DOWN TEST AT NO OBLIGATION!

It will open your eyes to Life-Linestarter's Stepped-Up Design and Performance. Mail the coupon today!

Westinghouse Electric Corporation
Box 868, Pittsburgh 30, Pa.

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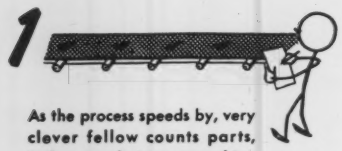
YOU CAN DO THIS *automatically*

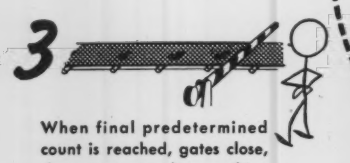


As the process speeds by, very clever fellow counts parts, inches, revolutions or machine operations up to 60,000 per minute without a mistake . . .

with a Potter Instrument Company, Inc.

At a precise preselected count short of the total, alert foreman signals for reduced speed or other preliminary control action . . .

Two Sequence Predetermined Electronic Counter



When final predetermined count is reached, gates close, shears cut or other machine control takes place—on the fly, without stopping . . .

With operation completed, tireless manager instantaneously calls for complete recycle without missing a count.

faster without human error

Potter instruments are working for manufacturers in every industry—controlling everything from the number of zips in a zipper to the number of pills in a bottle.

Potter counters can solve your problem if high speed and precise control are needed. No more flexible method of preselecting one, two or more counts in sequence exists. There are no moving parts, therefore wear, slippage and inertial effects are eliminated.

Have you a counting problem? We'd like to help.

WRITE FOR DESCRIPTIVE CATALOG

POTTER INSTRUMENT COMPANY
INCORPORATED
114 CUTTER MILL ROAD, GREAT NECK, NEW YORK

controls, H. H. Fowler, NPA administrator, was extremely careful to point out that the time has not come to talk of decontrol action on all materials. "Any impression to the contrary that might be derived from the flexibility of the Government's system of controls over materials and production must immediately be corrected," Mr. Fowler announced. "It is only by the continuation of this flexible but effective control system that an adequate flow of materials to essential defense programs can be maintained during the next 18 months or longer . . ."

Also revoked were the last remaining control on leather, and materials order M-53 limiting the distribution of cotton duck.

Report on World Situation: The International Materials Conference has made a report covering its first year of operation. This group, consisting of representatives of most of the Free Nations, has the responsibility of planning the allocation and distribution of short-supply materials and of securing acceptance of the plans by the participating countries.

The report, by giving a current appraisal of the Free World situation by commodities, provides an insight into the possible future supply situation in the United States. The U. S. is dependent upon foreign sources for a moderate or major part of its supply for those metals starred (*).

COPPER*: Although some improvement seems likely in late 1952, copper may well remain in short supply throughout the year.

ZINC: Will continue to improve, and may be sufficient to meet additional requirements later in the year.

LEAD: Will be adequate in 1952.

MANGANESE ORE*: Expected to be in easier supply in 1952.

NICKEL*: Continuance of the critical supply position for the remainder of 1952 is indicated.

COBALT*: Will continue to be in short supply for the remainder of the year.

TUNGSTEN*: Likely to be in short supply for the remainder of 1952 and for a further period thereafter.

MOLYBDENUM: Short supply for 1952 and for a further period.

Design Abstracts

(Continued from Page 162)

mere act of successfully placing a workpiece in a succeeding fixture could be utilized as an automatic inspection procedure.

Cam operated mechanisms form a large part of production line equipment. By utilizing standard elements like synchros, resolvers, induction potentiometers and other devices, it is possible to generate almost any desired function to great accuracies. Advantage can be taken of the equation solving properties of the servo which continuously computes the correct value of the controlled variable to satisfy the problem and provides this information in terms of some physical motion at any power level desired.

There is undoubtedly a considerable gap between the completely automatic factory of the future and present factories. Our factories today contain both human and machine elements. To what extent the human element can or should be eliminated in setting up an automatic factory is a complex problem. The proper blend of formal engineering, human engineering and economics should be employed to best meet the required long or short-term objectives.

From a paper entitled, "Automation of Machines and Processes," presented before the Greater New York Chapter of the ASTE in New York, May 1952.

Choosing Alternate Steels

By H. B. Knowlton

International Harvester Co.
Chicago, Ill.

THE first requirement for the selection of any type of steel is that the parts manufactured must give satisfactory performance in service. It is necessary to permit a range in composition of the type of steel, and in the hardness and other physical properties of the finished part. For these reasons, a performance test of parts made from a single lot of steel is not sufficient. In adopting a new

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It's because hard rubber is far more than "just a good insulator" that it's used in so many electrical parts. The familiar red magneto part above, for instance. It had to be wear-resistant and strong at 300° heat . . . and easily moldable with 17 inserts . . . in addition to high arc resistance (248) and high dielectric strength (600 v/mil). It's Ace Super Magnon hard rubber.
Many Ace compounds . . . some with tensiles as high as 10,000 psi. and moisture absorption as low as 0.04% . . . materials like the low power factor (0.6%), rigid X-2-B sheet for punched parts . . . and other Ace plastics such as high-impact (5.8 Izod) Ace-Hide; Saran, polyethylene, acrylics, etc., are covered in the new Ace Handbook. Keep it under your thumb when designing for today's production and tomorrow's plans.
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Internal stresses are reduced to an absolute minimum in PITCHLIGN bearings because the cage acts *only* in the direction of rotation at a point coincident with the roller orbit. Again, accumulated tolerances or wear of load carrying surfaces have no effect on the overall efficiency of the cage, since it is supported by the two integral flanges of the heavy outer race.

PITCHLIGN is not merely an improvement on a standard type bearing—it represents an entirely *new concept*, developed in an entirely new product . . . dimensionally interchangeable with precision needle bearings.

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type of steel, the part having the lowest allowable composition and properties must still give satisfactory service performance. Selection of a new steel, therefore, requires that the minimum properties produced will be as good as those of the steel which has been used in the past.

It is not always necessary to duplicate all of the properties of the original steel. For example, in the case of a part which is subject to failure at, or near, the surface it is not always necessary or even desirable to duplicate the physical properties of the center of the original piece. Only those properties essential to satisfactory performance are of concern.

Causes of Failure

Several factors are involved in the success or failure of different types of parts, and in the properties of steel which are required for satisfactory performance. Failure due to wear and abrasion is usually associated with insufficient hardness of the wearing surface, there are exceptions in the case of certain high alloy steels, but in the main, the statement holds true. Temporary deflections are associated with the modulus of elasticity, which is not materially changed by composition or heat treatment of the part; the only cure is increasing the section size. Permanent deflections are associated with stresses above the elastic limit, or yield strength. In general, raising the hardness and strength of the highest stressed area will be accompanied by an increase of yield strength. Breakage is the most serious type of failure and the one which causes the most strenuous complaints. Causes of breakage are:

1. Lack of strength at some point on the cross section to withstand the stress encountered at that point.
2. Inherent brittleness or lack of plasticity.
3. Internal stresses of a type and magnitude which will aid in causing failure. For example, residual tensile stresses in any part which is subject to bending or torsion will materially lower the service strength. This is frequently confused with brittleness since

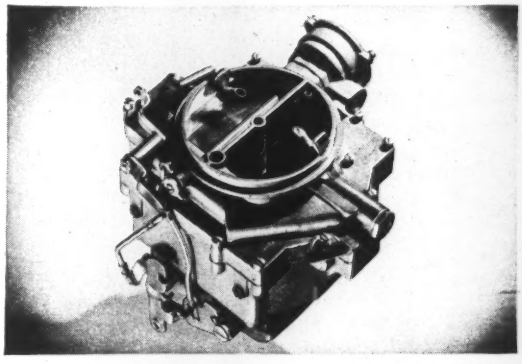
The Defense Production Administration's latest List of Basic Materials and Alternates shows

SPECIAL HIGH GRADE ZINC Moved to Group III

This means that this grade of Zinc—used for die casting—is in good supply and, by D.P.A. definition, should be used as an alternate for scarcer materials.

NO REASONABLE SUBSTITUTE FOR ZINC DIE CASTINGS

These ZINC Die Castings are the principal assembly components of the new four-jet automobile carburetor pictured below. By no other means of manufacture can such amazingly complex parts be produced at anything approaching comparable cost. After simple trimming operations, only the tapping of cored holes and the drilling of additional holes at odd angles are required to prepare these parts for assembly. Die casting is, truly, the shortest distance between raw material and finished part.



This four-jet carburetor is really two carburetors in one. The primary unit alone is in use until unusual acceleration is called for (as when passing a moving car), then the second unit comes into play.

While a carburetor bowl may be an extreme example of castability, it is an established fact that the physical and economic advantages of ZINC Die Castings are such that other materials and manufacturing methods seldom can be substituted. *With ample supplies of Special High Grade zinc assured, and with die casting equipment readily available, product engineers should continue to take advantage of the economies of ZINC Die Castings.*

If you are not now using ZINC Die Castings in your products, you may be overlooking a practical means of materially lowering your costs. Consult with any commercial die caster—or write to us. Ask for a copy of "Designing for Die Casting."

The New Jersey Zinc Company, 160 Front St., New York 38, N. Y.

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With peak work cycles becoming more crucial by the day throughout your operations, Twin Disc is all the more aware that *supplying* industry with high-performance Friction and Hydraulic Drives is only half the picture.

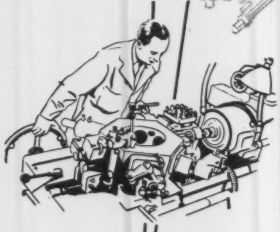
Today, it's the follow-through that counts—and Twin Disc assures that vital follow-through with the fastest, largest and most thorough Repair and Parts Service of any manufacturer of industrial friction and hydraulic drives.

68

To keep your equipment rolling, Twin Disc now has:

SIXTY Parts Stations and **EIGHT** Factory Branches, fully staffed by experts ready to provide efficient service and to train your own service crews;

$3¼ million inventory of repair parts and complete replacement units; distributed at 68 Strategic locations in every industrial area—throughout the Nation.



PRODUCTION schedule on service parts closely geared to requirements from the field.

TWIN DISC CLUTCHES AND HYDRAULIC DRIVES

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high internal stresses may permit a sudden failure when only a low external load is applied. Tests of the material after failure may show perfectly normal properties due to the fact that the internal stresses were relieved by the breaking of the piece.

4. Inherent brittleness of the steel. In any case where the service stresses, even in a localized area, are above the elastic limit of the material, some plastic deformation must occur in that locality. The steel must have sufficient toughness to permit plastic flow and produce a more uniform distribution of stresses in the highly stressed area. Lacking the minimum required ductility, the piece breaks with a sudden snap and shows a bright "crystalline" fracture. However, once the steel has sufficient toughness to prevent this brittle type of fracture, higher degrees of toughness do not produce any additional merit. Far too great emphasis has been placed upon variations in notch toughness of different steels, particularly at high levels which do not seem to be associated with success or failure of finished parts.

Boron Adds Hardness

The use of the boron alloy steels offers one of the most attractive means of conserving alloys because the boron addition agents produce the greatest increase in hardenability in proportion to the per cent of material added. It seems probable that the boron alloy steels may be substituted for the more conventional alloy steels for parts which are heat treated for strength and toughness, and some surface hardness. The boron alloy steel should be selected on the basis of duplicating the minimum hardenability to a distance on the Jominy specimen corresponding with the cooling speed of the critical section of the production part. It is not always necessary to duplicate the entire hardenability band. It is safer to calculate the minimum strength which will be obtained at the point of highest stress on the cross section, on the basis of the minimum hardness which will be obtained at this point after a production quench-

The direct-process prints and blueprints received from vendors are reproduced on Autopositive Paper when extra copies are needed for the drafting room or shop. Deletions and additions can be made readily on Autopositive intermediates . . . saving drafting time.

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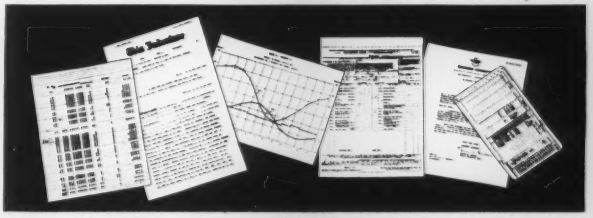

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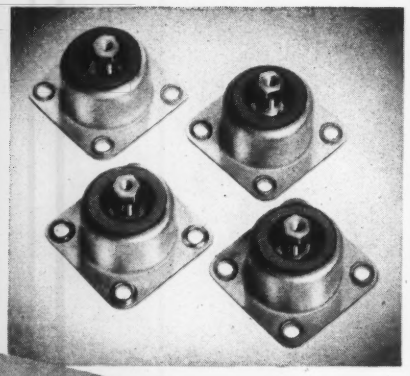

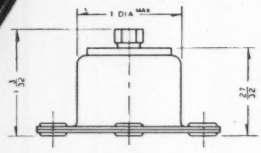

Photo courtesy Vapor Heating Corp.

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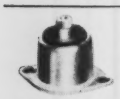

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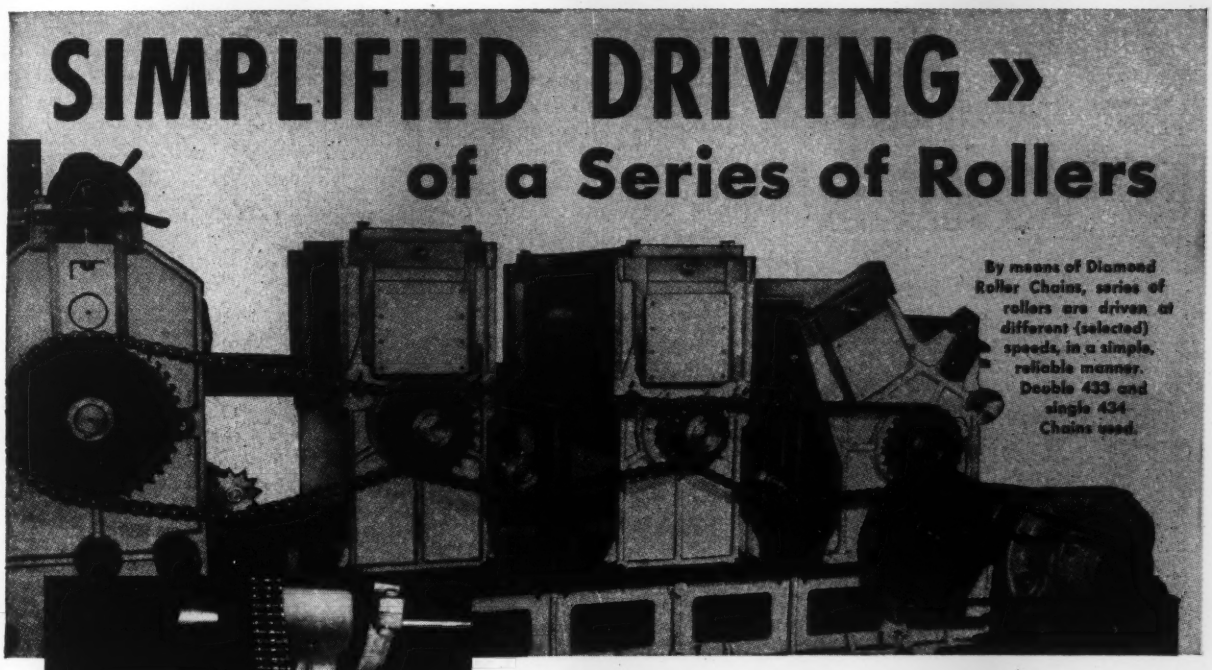
ing and drawing treatment, rather than on the basis of tensile specimens taken from the center, or half radius positions. Similarly, minimum physical properties, representing the bottom of the expected hardenability band for the boron steel, are more reliable than the most elaborate of service tests made upon parts manufactured from lots of steel representing the middle or upper portion of the hardenability band.

Toughness Is Essential

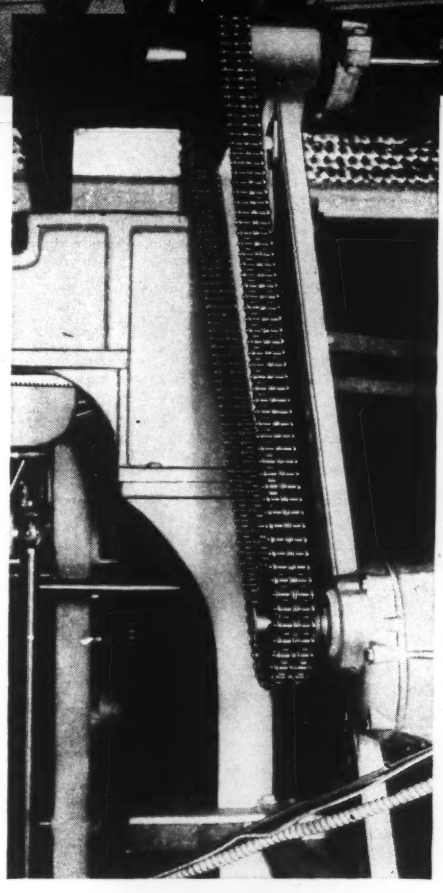
It is absolutely imperative that the steel selected shall have sufficient toughness to prevent brittle types of service failures. By this is meant to prevent failure from originating in a brittle manner. Practically all fatigue failures show a small area representing the last portion to break, which has the characteristic appearance of brittle fracture. For any given part a certain minimum toughness is required to prevent brittle origin of failure. Higher degrees of toughness may not be of any greater value. The minimum toughness required for successful performance of many automotive parts is frequently lower than may be supposed due to the fact that the designer has avoided sharp notches and other stress raisers. It is sufficient to duplicate the minimum toughness which has been satisfactory in the past. Much higher degrees of toughness are required for projectiles, armor, or any other parts which are subjected to application of stress at ballistic velocities. Some writers have laid great stress upon the fact that the boron steels may show less toughness than other alloy steels under conditions of slack quenching or high tempering. It should be determined whether the final properties are adequate for the actual application.

Boron alloy steels are being used satisfactorily for certain case hardened parts, particularly case hardened gears. More difficulties have been encountered, however, with case hardened parts than with all types of heat treated parts. The addition of boron has the greatest effect upon the hardenability of the core, and the least effect upon the hardenability of

SIMPLIFIED DRIVING » of a Series of Rollers



By means of Diamond Roller Chains, series of rollers are driven at different (selected) speeds, in a simple, reliable manner. Double 433 and single 434 Chains used.



On the Clermont Sheet Former Matzo Machine, the power transfer medium is Diamond double 433 Chain.

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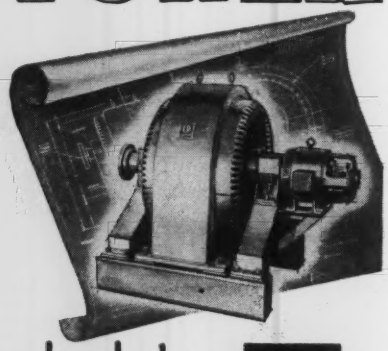

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high carbon portions of the case, particularly any portion containing 0.90 carbon or above. Consequently, some difficulties have been reported with failure of the surface of large sections to harden properly, while the high hardenability of the core has sometimes caused excessive distortion. Lowering the carbon content of the steel is sometimes beneficial, but in some cases has caused difficulties with machinability due to the unusual softness of these very low carbon steels.

The use of boron steels is only one approach to the problem of conservation of alloying elements. The new 8000 and 8100 series steels without boron have advantages for some applications. Furthermore, plain carbon steels, such as 1045 and 1050, with the help of induction hardening, torch hardening, and special heat treatments involving drastic quenching, have been found very valuable for certain applications. In some cases, performance tests have shown the specially treated carbon steels to be equal, or superior, to the older alloy steels. The control of residual stress set up by heat treatment is one of the most important factors influencing the service performance of finished parts. Austempering, martempering, and the special treatments just mentioned, all have an important effect upon the residual stresses left in the steel. Improved techniques for heat treatment of carbon steels probably offer the greatest possibilities for conservation.

From a paper entitled, "Boron and Other Low Alloy Steels," presented at the SAE Annual Meeting in Detroit, Mich., January 1952.

Electric Resistance Strain Gages

By J. A. Sweeney Jr. and D. K. Schaeve

Barber-Colman Co.
Rockford, Ill.

FOR measurement of strain, the oldest types of devices rely on levers or similar mechanical amplification to produce a visual indication. The mechanical extensometer is an example. Although these devices are simple and usual-

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EXPORT	Mercator Corp. 438 Walnut St. Reading, Pa.
CANADA	Railway & Power Engineering Corp. Ltd.

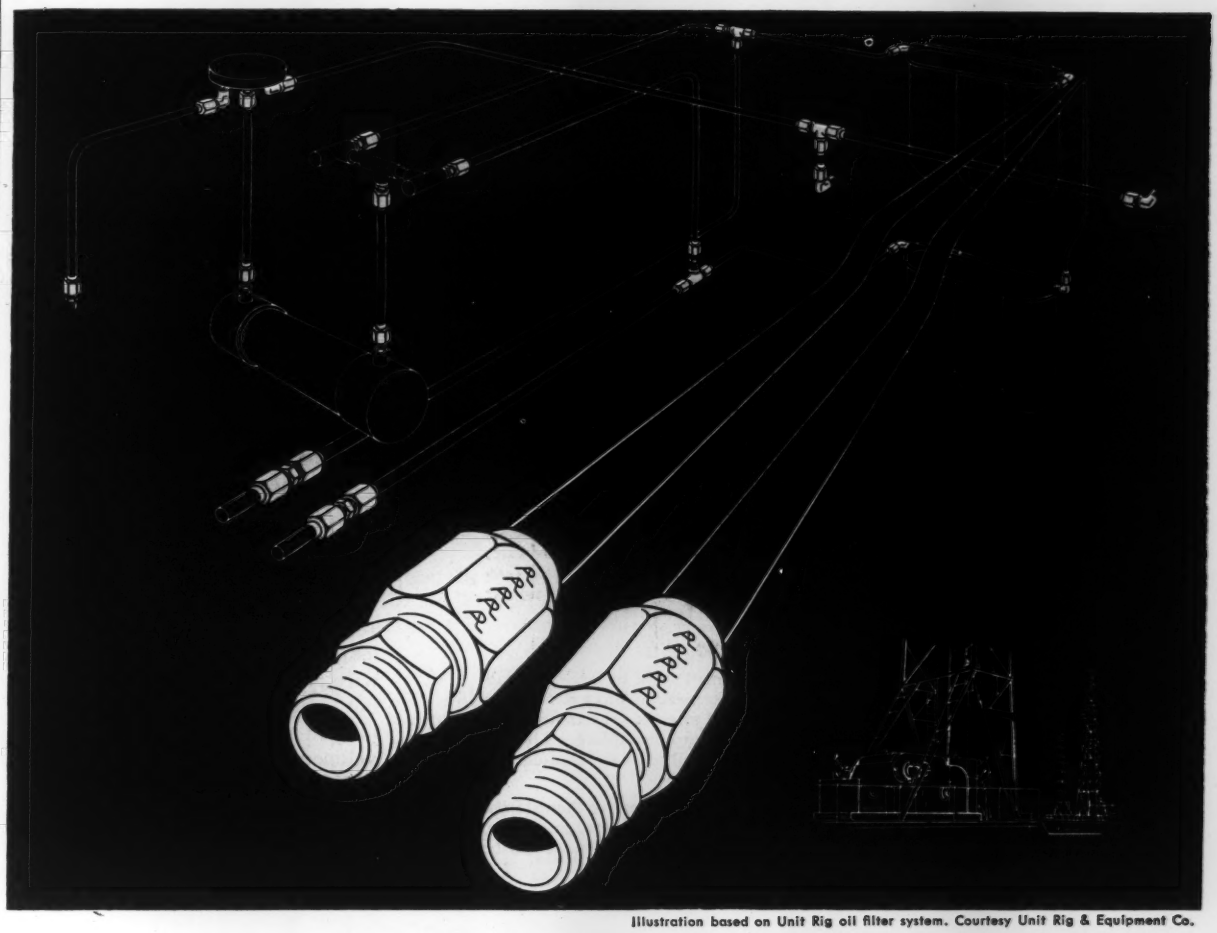

Illustration based on Unit Rig oil filter system. Courtesy Unit Rig & Equipment Co.

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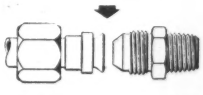

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AMBLER CHEMICALS ACP PROCESSES PENNA.

Technical Service Data Sheet
Subject: RUST PROOFING WITH PERMADINE®

INTRODUCTION:

Ferrous metal parts that have been Permadized in a zinc phosphate chemical solution and then "sealed" with a rust-preventive oil such as "Granoleum" are effectively protected from rust-damage. In addition, if the surface is accidentally chipped or scratched, rusting is confined to the exposed area.

Rust proof coatings find many practical applications. During World Wars I and II most small arms were rust proofed by phosphate coating and impregnated with chromic acid and a rust preventive oil, or cutback petrolatum. This not only provided excellent corrosion resistance but also yielded a dull black non-reflecting surface. Rust proof finishes are now used widely on hardware, firearms, cartridge clips, metallic belt links, miscellaneous forgings and castings, tools, unpainted replacement machine parts, and many other similar items such as bolts, nuts, and washers.

THE PERMADIZING PROCESS:

For the most effective rust proofing of large or small work in large or small production, "Permadine" is used in tanks in an immersion process, with the bath heated to 190°-210°F., coating time 20 to 30 minutes. The coated parts are then rinsed in clean water, and then in a controlled dilute acidulated solution. After drying, a suitable corrosion-resistant oil such as "Granoleum" is applied.

Operations can be carried out with the work in crates, or hung from hooks, utilizing an overhead rail and hoists. For large volume production, automatic equipment can be used to mechanize the line. Small parts can be treated in tumbling barrels.

"PERMADINE" MEETS SERVICE SPECIFICATIONS:

The protective "Permadine" finish meets U.S.A. 57-0-2C; Type II, Class B, and equivalent requirements of:

MIL-C-16232,
Type II
U.S.A. 51-70-1,
Finish 22.02, Class B
AN-F-20
Navy Aeronautical M-364
JAN-L-548

"PERMADINE" DATA CHART

Type of coating	Zinc phosphate
Object of coating	Rust and corrosion prevention
Typical products treated	Nuts, bolts, screws, hardware items, tools, guns, cartridge clips, fire control instruments, metallic belt links, steel aircraft parts, certain steel projectiles and many other components
Scale of production	Large or small volume; large or small work
Method of application	Dip Barrel tumbling, racked or basketed work
Equipment notes	Immersion tanks of suitable capacity. Cleaning and rinsing stages can be of mild steel. Coating stage can be of heavy mild steel or stainless steel.
Chemicals required	"Permadine" No. 1
Pre-cleaning methods	Any common degreasing method can be used, Alkali cleaning ("Ridosol"), Acid cleaning ("Deoxidine"), Emulsion-alkali cleaning ("Ridosol"-"Ridoline"); vapor degreasing, solvent wiping, etc., are examples. Acid cleaning may need to follow other cleaning methods if rust or scale is present.
Bath Temperature	190° - 210°F.
Coating time	20 - 30 minutes
Coating weight range Mgs./Sq. Ft.	1000 - 4000
Technical Service Data Sheets	No. 7-20-1-2 T. M. No. 5

CHEMICALS ACP PROCESSES

WRITE FOR FURTHER INFORMATION ON "PERMADINE" AND YOUR OWN METAL PROTECTION PROBLEMS

CHEMICALS ACP PROCESSES

ly direct reading, they are bulky and are limited to the measurement of static or slowly varying strains.

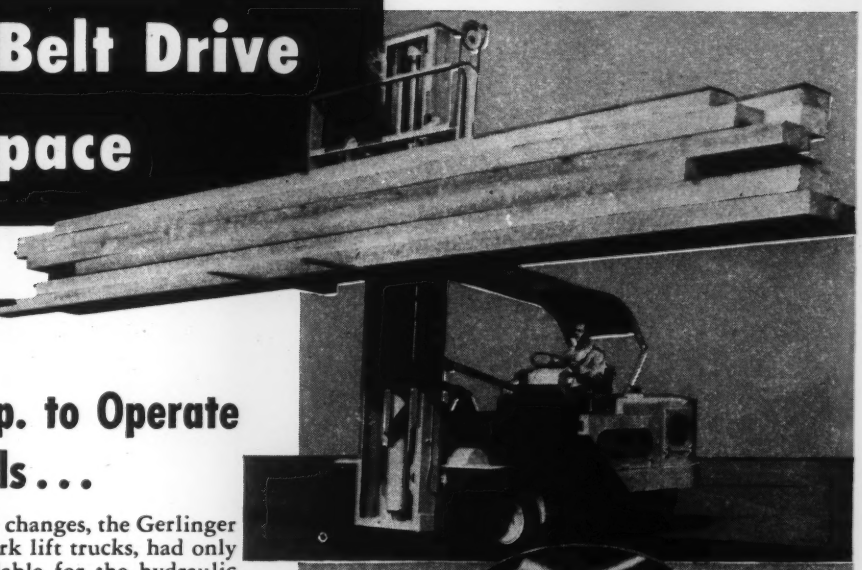
With the advent of advanced methods of electrical instrumentation, many devices have been developed which respond to strain by a variation in some electrical property. Although there are, for special purposes, satisfactory inductance gages, in which the strain varies the air gap of a magnetic circuit, and capacitance gages, in which the spacing between parallel insulated plates is varied, by far the most useful and versatile of the strain measuring devices is the electrical resistance strain gage.

Compactness Aids Testing

Lord Kelvin discovered prior to 1856, that the resistance of a length of wire is altered when the wire is stretched. However, it was not until recent years that the bonded-wire strain gages were developed to utilize this principle. These gages, consisting of a grid of very fine wire bonded between thin sheets of paper, are cemented directly to the member under test. Smaller than a postage stamp and made in gage lengths down to 1/16-inch, they measure the strain in a small area rather than the average strain over a considerable gage length, an important consideration in irregular shaped structures. These gages respond with good accuracy to either static strains or dynamic strains with frequencies up to several thousand cycles per second. They are remote indicating, and the output may be observed visually or recorded for study. However, the prime advantage of electrical resistance-wire strain gages is that their presence has practically no effect on the structure under test. The principal disadvantage is their extremely low output, requiring amplifiers and considerable auxiliary equipment unless the strains are very large.

Since the change of resistance of an electrical-resistance strain gage is relatively small (a stress of about 15,000 psi in steel being required for a 0.1 per cent change of resistance) it is usually used in some form of bridge circuit. Such a bridge in its simplest form ap-

Unique 4 Belt Drive Fits 2¼" Space



Transmits 34 h. p. to Operate Hydraulic Controls . . .

Unless they made costly changes, the Gerlinger Carrier Co., makers of big fork lift trucks, had only 2¼" on the crankshaft available for the hydraulic pump drive.

A standard V-Belt drive to carry a load up to 34 horsepower would have required 5½". It appeared that a chain drive was the only type that could handle the load and fit the space. Early trucks, therefore, were equipped with chain drives on the hydraulic pumps.

In service, however, chains gave trouble. It was impractical to encase them and their speed was so high (3000 ft./min.) that they threw off all lubricants, and wore out rapidly. Gates engineers were asked for a solution.

Drawing upon a background of more that 20 years of *Specialized* Research in V-Belt engineering, Gates engineers worked out a drive using four small specially designed V-Belts. This drive fits into the crowded space between engine and fan belt and yet has ample capacity to handle the heavy load.

This V-Belt Drive Is Another Practical Example of Gates Specialized Research

V-Belt drive has many advantages

Unlike the chain drive, V-Belts require no lubrication, yet are quiet and positive and the multiple strands are an advantage because they assure uninterrupted operation. If one belt breaks, the others continue to carry the load until replacement can be made. A further advantage is that the early lift trucks can be equipped with the new drive at a minimum cost.

This is another example of the practical value of Gates engineering know-how applied to a critical design problem. Only rarely, of course, are special V-Belts required to solve such a problem, but the same engineering skill and experience is available to you—right in your own plant—for the solution of *any* power transmission problem you may have.

Phone for a Gates Field Engineer

Whenever you have a difficult drive to design—or if some difficulty develops on any drive in your plant or if you only want to know what V-Belts to use for the most efficient, lowest cost service on any particular drive—just pick up your phone book and call the number listed under "Gates Rubber."

A Gates field engineer will call on you and put at your service all the facilities of Gates *Specialized* Research on V-Belts—*without the slightest obligation.*

There are Gates engineering offices and jobber stocks in all industrial centers of the U.S. and 71 foreign countries.

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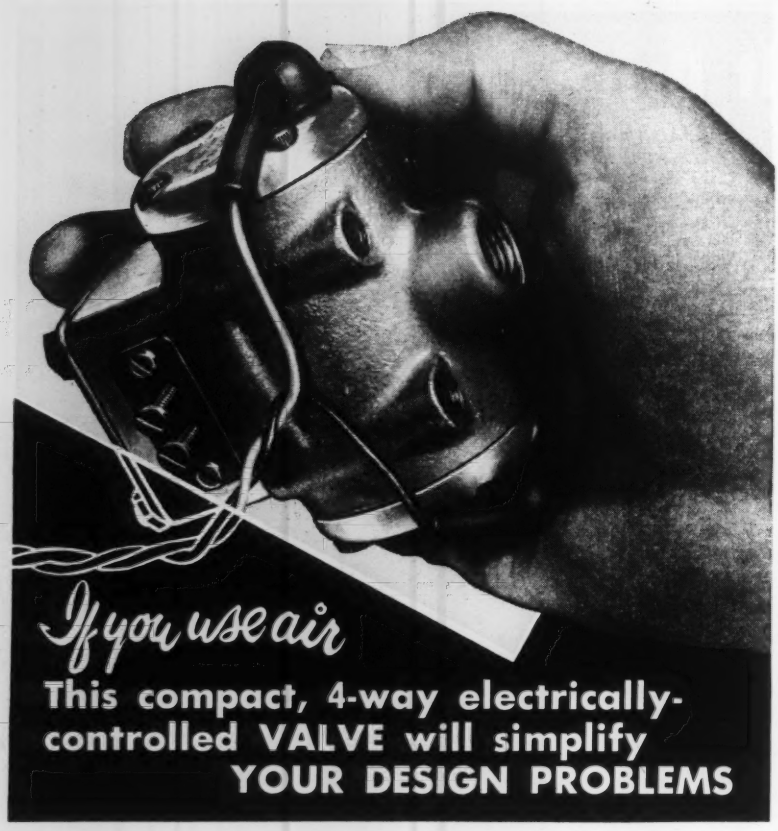
Gates VULCO ROPE DRIVES



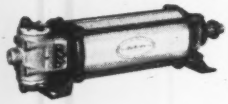
If you use air

This compact, 4-way electrically-controlled VALVE will simplify YOUR DESIGN PROBLEMS

The Bellows air-powered, electrically-controlled air valve is so fast it will complete 2000 or more movements a minute. Yet its unique low voltage solenoids will operate all day without discernible hum, pounding, or overheating. So sturdily built, in fact, that we guarantee its solenoid control units against burnout.

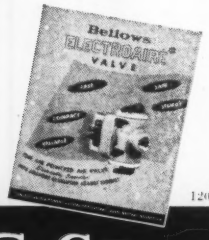
The Bellows Electroaire Valve* is so compact it can be held in the palm of a hand, yet it combines in one complete unit a four-way directional valve, piston speed regulators, and low voltage electrical controls. It will operate safely and efficiently even if submerged, covered with coolant, or piled high with dirt or chips. It is self-adjusting to widely varying air pressures . . . operates on 5 to 150 lbs. of air.

Made in ¼", ⅜" and ½" port sizes, the Bellows Electroaire valve can be adapted for direct connection to, or remote control of any standard air cylinder. It is a built-in feature of all Bellows "Controlled - Air - Power" Devices arranged for electrical control.



Write for These Free Bulletins

Case histories, wiring diagrams, technical data on the Electroaire Valve and other Bellows pneumatic equipment. Ask for Bulletin AV-300 and CL-30. Address: The Bellows Co., Dept. Akron 9, Ohio.



*TM Registered — Patent Pending

1201

The Bellows Co.

AKRON 9, OHIO

FASTER, SAFER, BETTER PRODUCTION — WITH "CONTROLLED-AIR-POWER"

pears in *Fig.* 1.

For such a bridge, the following fundamental equations apply:

$$E_0 = E_i \frac{R_1}{R_1 + R_4} - E_i \frac{R_2}{R_2 + R_3}$$

or

$$E_0 = E_i \frac{R_1R_3 - R_2R_4}{(R_1 + R_4)(R_2 + R_3)}$$

The simplest method of measuring strain with such a bridge is to rebalance the bridge to a null by varying one or more arms of the bridge, the amount of the change being a measure of the unbalance. This method can be used to a high degree of accuracy with static or very slowly varying strains, but obviously is of no value in measuring dynamic strains. However, it may be noted from the bridge equations that for small unbalances, the unbalance voltage is practically proportional to the degree of unbalance. By recording this voltage by suitable means, a continuous record of strain is obtained, whether static in nature or of high frequency.

As mentioned previously, the output of the bridge is small and an amplifier must be employed to actuate the recording means. The requirements on such an amplifier are severe, as it must have flat frequency response from zero to the highest frequency to be recorded. Although this is not an insurmountable obstacle, the stability problems encountered in d-c amplifiers operating at low signal levels are well known and appreciated.

Fortunately, the same fundamental bridge equations apply when the bridge is energized with an alternating voltage, providing

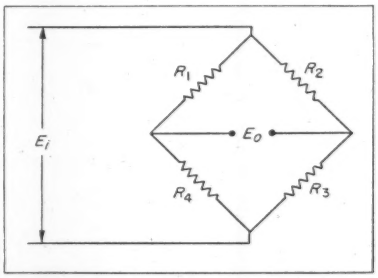


Fig. 1—Simple bridge circuit used with electrical resistance strain gage. Unbalance in bridge caused by resistance variations in wire when stretching indicates strain

Prepared for Special Work

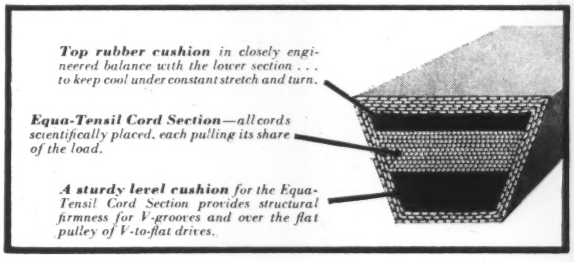
NATURALLY every U. S. Rubber V-Belt has special properties, depending on its ultimate purpose.

But if a belt has to handle conditions not usually found on the average drive, then it has to be "prepared" for that job. If an oil condition is involved, the belt may be made with an oil-resistant cover, or, if the condition is extreme, the entire belt may be made of oil-proof construction.

Where generation of static electricity occurs, the V-belt is so compounded that it becomes a conductor of electricity.

Only U. S. Rubber gives you *all* of these 4 V-Belt advantages:

1. *Major part of inherent stretch worked out by mechanical means, yet enough elasticity is retained to allow belt to withstand severe shock loads.*
2. *Cords treated with latex, to reduce heat generated by constant flexing, and to get maximum adhesion between the component parts of the belt.*
3. *Protective jacket that increases grip while keeping out dirt and prolonging wear.*
4. *Unique Equa-Tensil Cord Section—exclusive with U. S. Rubber —which provides efficient pull and strength under diverse operations.*


Top rubber cushion in closely engineered balance with the lower section . . . to keep cool under constant stretch and turn.
Equa-Tensil Cord Section—all cords scientifically placed, each pulling its share of the load.
A sturdy level cushion for the Equa-Tensil Cord Section provides structural firmness for V-grooves and over the flat pulley of V-to-flat drives.

For more information write to address below.

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compensation is made for reactance effects. If the exciting frequency is at least several times the maximum frequency of strain variations to be recorded, amplification takes place at essentially a constant frequency, and frequency response of the amplifier is of little importance. Thus a relatively simple and stable audio frequency amplifier may be used. An additional important advantage is the elimination of thermocouple effects, which may become troublesome in a low level direct-current system, especially if the leads are fairly long, and considerable temperature difference exists between portions of the circuit.

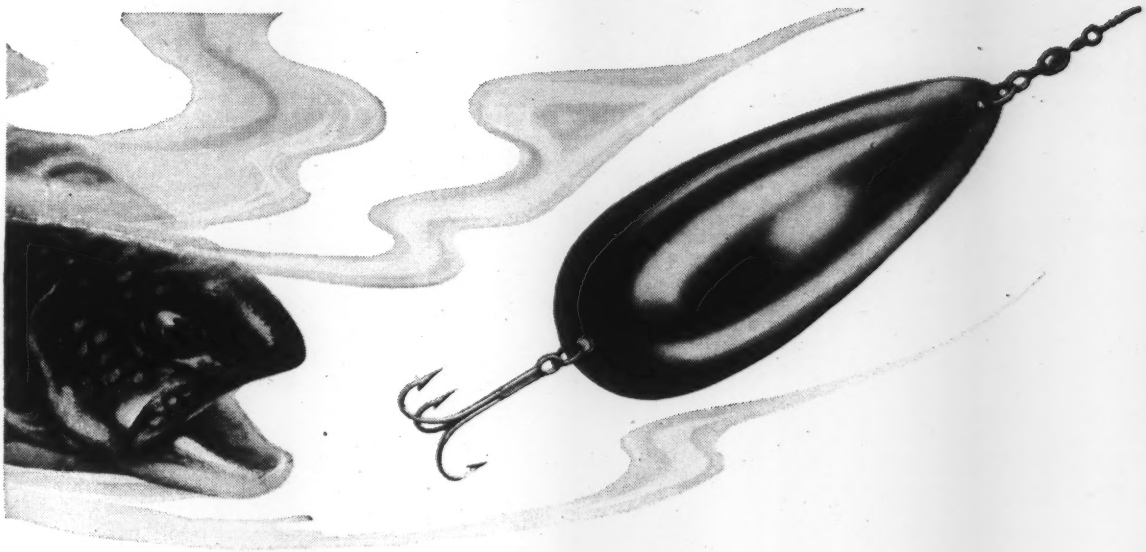
From a paper entitled "Electric Resistance Strain Gage Studies of Dynamic Loads in Machine Tools" presented at the 4th Annual AIEE Special Conference on Machine Tools in Rockford, Ill., November, 1951.

Electromechanical Machining

By Malcolm F. Judkins

Chief Engineer
High Temperature Alloys Div.
Firth Sterling Steel & Carbide Corp.
McKeesport, Pa.

ONE of the latest developments in fabricating processes for hard materials is electromechanical machining. In this process, electrical energy is used directly to effect metal removal, without converting electrical to mechanical energy and using the force to propel the cutting edge through the work. Electrical forces are generated between the tool and work of sufficient magnitude to exceed the latter's tensile strength, and cause rupture. The process is mechanical, not thermal. Metal particles are detached from both work and tool without melting, leaving the surfaces produced free from physical or chemical changes. The tool, of the shape to be produced, is made the negative electrode and the work, the positive terminal. Required electrostatic forces are generated by the repeated charge and discharge of a parallel capacitor. Cutting action occurs in a dielectric fluid (an insulating nonelectrolyte) which is usually a hydrocarbon. Spark discharge across

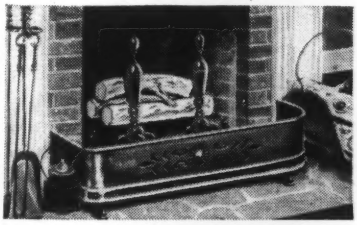


What's the big attraction?

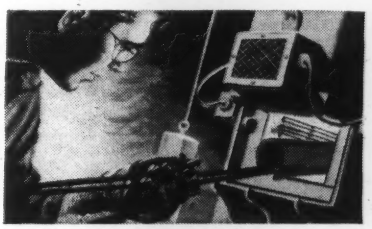
The same brilliance that catches Mr. Trout's eye is also found on a wide range of brass and copper products, from costume jewelry to the gleaming brightwork on a ship.

The clean, bright surface of Chase metals doesn't just happen . . . it is controlled in research laboratories by Chase metallurgists . . . it is checked and tested every step along the way to the finished sheet, rod, wire or tube.

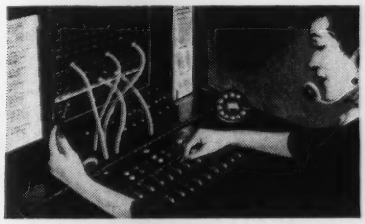
Chase brass and copper products are available, subject to government controls, through dealers, and jobbers across the nation and through Chase's 23 convenient mill warehouses.* Chase Brass & Copper Co., Incorporated, Waterbury 20, Conn.



Chase brass and other copper alloys range in color from rich red to bright yellow. The right color for each product and use is one of the features of Chase research and quality control.



When the Chase Technical Advisory Service is asked to solve a problem by a manufacturer, Chase metallurgists will often find the right answer in this research laboratory test furnace.



Patented Chase Telnic® Bronze makes better switchboard parts. Chase research developed Telnic for high strength, excellent machinability, corrosion resistance, and conductivity.

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S. S. WHITE FLEXIBLE SHAFTS

The two products illustrated presented the same problem — the transmission of rotary movement around a turn. In both cases, the designers could have done the job with combinations of straight shafts, bevel gears, universals or other mechanical elements. Instead, they used S.S.White flexible shafts, which not only saved parts but eliminated costly assembly time and operations, as well.

For a really simple solution to your own power drive and remote control problems, consider the use of S.S.White flexible shafts. Their extreme simplicity, adaptability and ease of application are time-and-money-saving features.

WRITE FOR THIS 256-PAGE HANDBOOK

it gives comprehensive, authoritative facts and data on flexible shafts and their application. A request, direct to us, on your business letterhead and indicating your position will bring you a free copy. Write today.

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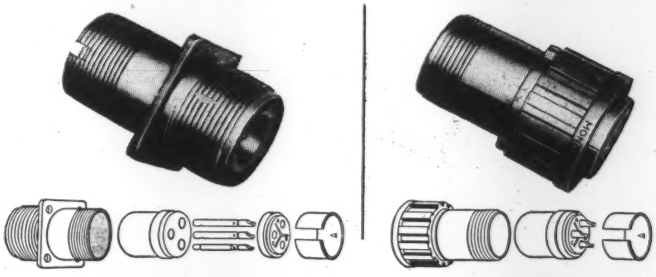
the open gap or space between the electrode and work can then liberate hydrogen which deionizes the spark path, permitting frequent cycle repetition. The tool penetrates the work without physical contact. Feed or advance of the cutting electrode is automatically controlled to maintain as closely as possible the proper spark gap for the applied potential. This control prevents contact which might generate an arc. Dielectric fluid also serves to carry away the loosened particles from the work area.

The standard model machine resembles a jig borer in physical appearance, being of the vertical-spindle knee and column type. The work-holding table can be traversed longitudinally and transversely. The fluid receptacle is mounted on a 360-degree rotatable base. The spindle carrying the electrode can be either revolved and advanced as for threading or boring, reaming, etc., or can be moved vertically without rotation as in the forming of other than round holes. The spindle is actuated by a lead screw driven through bevel gears and a reduction gear by an infinitely variable speed dc motor. The associated equipment includes the necessary means for charging and controlling the cutting motions.

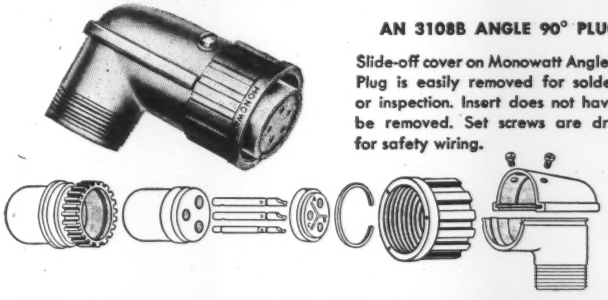
Tapping and Threading: One of the unique applications of this method is that of tapping or threading. For many applications of sintered carbide involving heavy loads, high temperature or impact, the conventional method of joining carbide sections to the supporting steel shank or other supporting structure by means of brazing is entirely unsatisfactory. This new method provides a convenient means of incorporating screw fastening devices. The threading is done quite simply using, whenever possible, a threaded hollow brass tube as the tool. Unlike conventional machine practice involving the use of a tap drill before inserting the tap, the work is performed in a single operation leaving a core slightly smaller than the inside of the tube which can easily be broken off in case the hole is blind. In a blind hole, the last few threads will be

Let MONOWATT help you with your AN CONNECTOR PROBLEMS



AN 3100A WALL MOUNTING RECEPTACLE **AN 3106A STRAIGHT PLUG**

Snap-In sleeve on Monowatt Wall Mounting Receptacles and Straight Plugs allows easy access to insert for soldering and inspection. Sleeve snaps in and cannot work loose, yet can be released quickly with a small screwdriver for removal of insert. With this new type sleeve and Monowatt's one-piece solid housing it is possible to use a solid shell connector in applications which would otherwise call for a split shell. Extra weight and possible loosening of threaded parts under vibration is eliminated.



AN 3108B ANGLE 90° PLUG

Slide-off cover on Monowatt Angle 90° Plug is easily removed for soldering or inspection. Insert does not have to be removed. Set screws are drilled for safety wiring.

Is it a question of delivery? Meeting specifications? Reducing assembly and inspection costs? The Monowatt Department of General Electric Company can help you solve such problems.

Monowatt is now supplying AN connectors for Lockheed, Chance Vought, Minneapolis-Honeywell, and many others. With complete, modern facilities for mass-production, we can offer, on a fast-delivery basis, connectors conforming to latest Government specifications at competitive prices.

If you require AN connectors—or any of the wiring components shown below—you will be interested in what Monowatt can do for you.

For complete information, mail the coupon below.

And you can count on MONOWATT for all types of electrical components — made to your specifications

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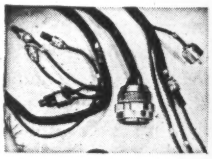

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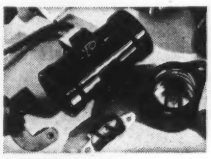

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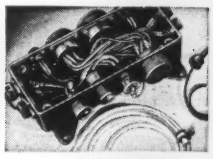

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☐ Please quote on attached specifications.

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at a price you can afford

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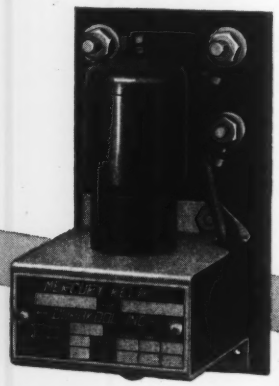

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Controlled time available from .15 to 20.0 seconds in either normally open or normally closed actions. 3 to 4 week delivery. No waiting. Your production schedule is met.

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★ No false contacts
★ No chatter
★ Quiet in operation
★ Eliminates double contacting or breaking of circuit

Durakool ALL-STEEL MERCURY Timers

imperfect or incomplete due to electrode erosion, but since good mechanical design provides clearances at the bottom of such holes, no difficulties are encountered. In Class 2 threads, which are easily produced, the stud will ordinarily assemble into the threaded hole to within about $\frac{5}{8}$ of a turn of the bottom.

Shape Cutting: The method is ideally suited to the forming of both simple and intricate interiors, both blind and through, and to exterior shaping as well. When round holes of $\frac{1}{4}$-inch diameter are to be made, the electrode is usually hollow and is rotated. This confines the cutting action to the wall thickness of the tube and permits pressurized supply of the dielectric fluid through the tube tool to assist in clearing chips and greatly increases the speed of cutting. As a by-product, a core of the material cut slightly smaller than the inside of the tubing may be salvaged. Holes, from approximately 0.004-inch diameter up to the largest brass tubing available, can be produced even in the hardest metals including sintered carbides of all types. Intricacy is of no consequence, inasmuch as any shape which can be produced in brass, which is cheap and easily formed, can be duplicated in any metal.

Machining Accuracy: Size of the opening or of the shape produced is a direct function of the electrode dimensions and the applied voltage. If 50 volts are used to charge the condenser, the hole will be about 0.003-inch larger than the electrode and of the same shape. If 150 volts are used, the hole will be approximately 0.024-inch larger than the electrode. Accuracy of approximately plus or minus 0.0005-inch is regularly achieved. On finish cuts at low voltage, the surface quality can be as high as 26 microinches. Accuracy of spacing between centers of openings made through the same piece is limited only by the precision with which the table is moved and positioned by the cuts. There is no torque or thrust involved because there is no contact between the tool and work. This factor, which contributes so largely to inaccurate spac-

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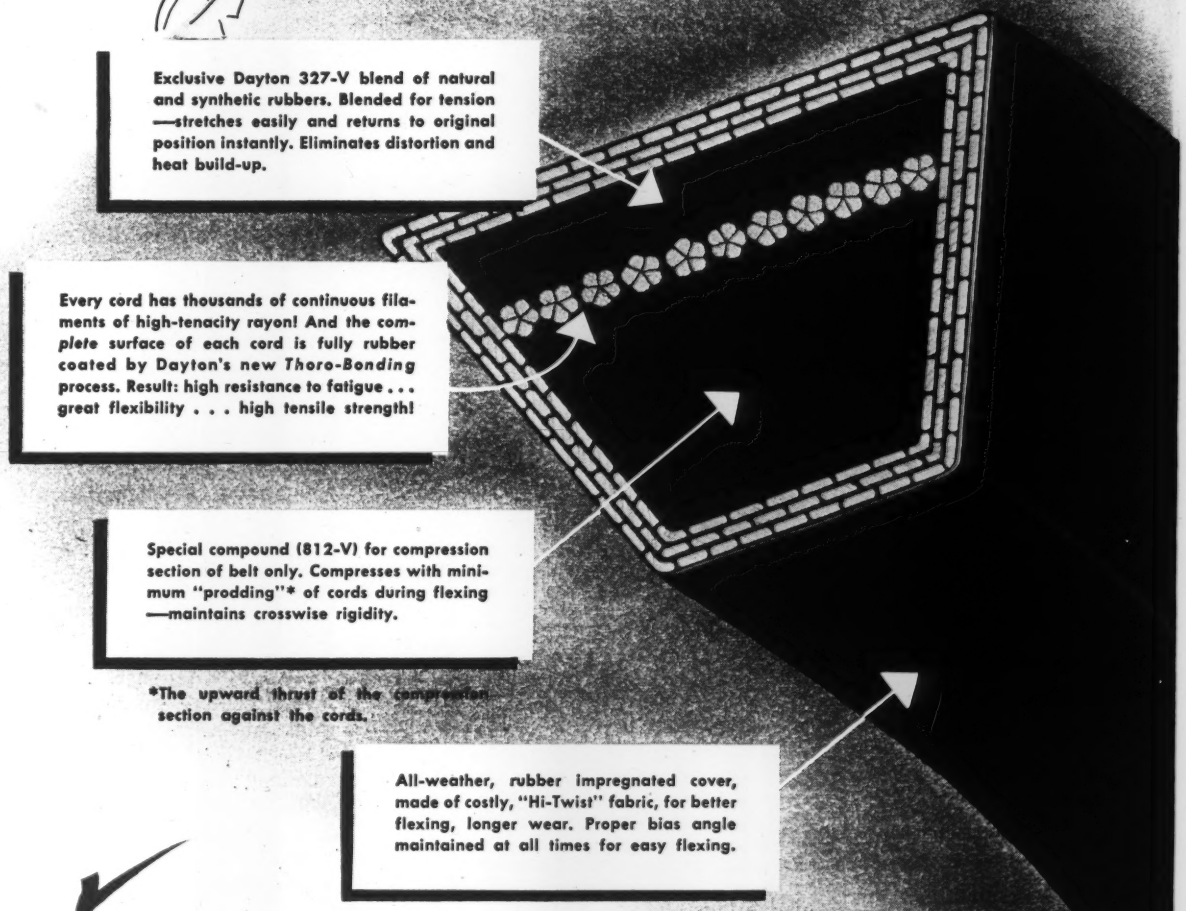

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*The upward thrust of the compression section against the cords.

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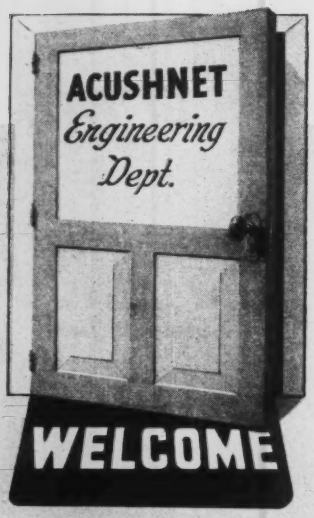

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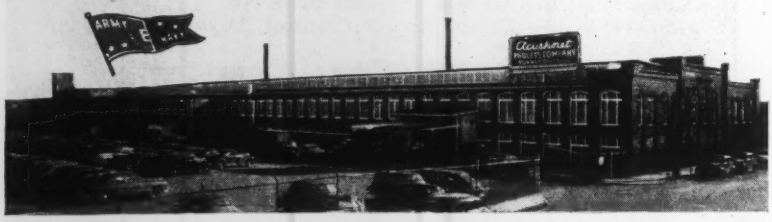

Address all communications to 762 Belleville Ave., New Bedford, Mass.

ing of holes made by conventional methods, is nonexistent.

Production Rates: The original machine could cut tungsten carbide at the rate of about one inch per hour. Later models cut at the rate of several inches per hour, and further improvement which might conceivably culminate in rates of several inches per minute is within the realm of possibility. In evaluating these rates, it must be remembered that the principal application of this method is to metals which cannot be machined at all by conventional methods. However, the principle is capable of further development which may make it possible to compete, both time and cost-wise, with such operations as conventional drilling, boring, and reaming, and perhaps even broaching.

From a paper entitled "Electro-Mechanical Machining of Hard Materials," presented at the Twentieth Annual Meeting of the ASTE in Chicago, Ill., March 1952.

Evaluating Mechanical Shock Resistance

By Bernard Goldberg and T. E. Pardue

Naval Research Laboratory
Washington, D. C.

STRUCTURAL parts of military vehicles, machinery and other equipment are frequently subjected to shock loading which produces a damped train of high-amplitude oscillations. Failure of a part often occurs after a relatively small number of strain cycles. One problem in the design of machinery and equipment for such severe conditions is the choice of materials for components which will withstand a relatively small number of strain cycles involving large plastic deformations.

Methods and apparatus for measuring resistance of materials to mechanical shock have been studied in the Naval Research Laboratory. The test materials used were a group of sand-cast aluminum alloys of special interest to the Navy.

It is of considerable practical interest to know whether or not shock resistance can be inferred

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In designing machine tools, as in planning countless other products, OSTUCO Steel Tubing provides an endless pool of practical ideas because of its *unlimited adaptability*. Collets, chucks, spacers, spindles, bearings, shafts, ferrules, and handles are but a few of the applications.

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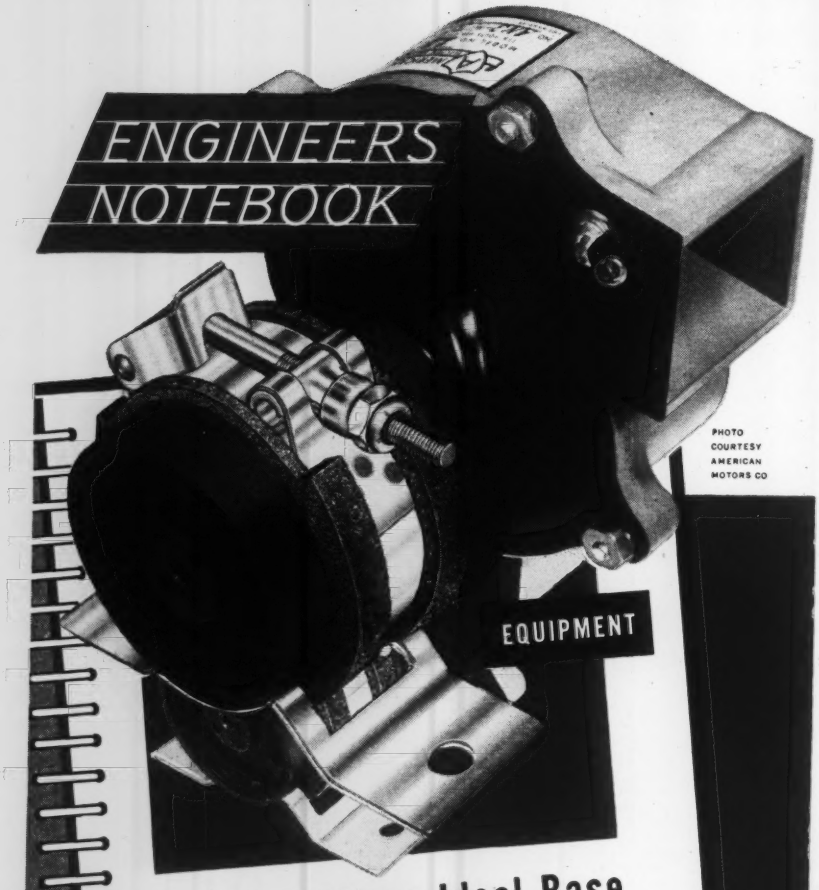

Support Clamp Ideal Base for Fractional-hp Motor

A Marman Support Clamp is used as a base on the American Motors Blower for cooling electrical systems. It provides a secure, light-weight attachment that is vibration-proof and trouble-free. This clamp is achieved by simply adding a cradle or support to a standard Marman Band Clamp and thus requires no special design or production. Used for almost any motor or other attachment application, it allows mounting at all angles, quick detachment because of the patented Quick Coupler Latch and a highly compact efficient assembly.

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FOR ADDITIONAL INFORMATION ON THIS PRODUCT ASK FOR ENGINEER'S NOTEBOOK #18. WRITE DEPT. M-7

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18

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from readily obtainable physical data rather than from the shock tests. There are well-known disadvantages in comparing data from other types of tests. However, since one purpose of this study is to establish methods and procedures for determining shock resistance, any correlation between different tests is of interest.

The following observations were made:

1. Very poor correlation exists between shock resistance and ultimate tensile strength

2. Fair correlation exists between ductility and shock resistance. However, relative endurance levels of some alloys were higher than their percent-elongation relationship in the tensile test

3. Shock resistance shows fair agreement with impact resistance as measured by the Charpy and Izod tests. Alloys having poorest shock qualities also have lowest impact resistance. However, the superior shock resistance of some alloys is not shown by their relative standing in the Charpy and Izod data

4. Data obtained using a fatigue machine show fair agreement with data from the shock tests if angular bending of the loaded specimen is chosen to correspond to shock intensity rather than the usual conditions of constant load

5. Measurements made on the fatigue machine show that the alloys which have the greatest total energy absorption for a given number of revolutions to failure also have the highest shock resistance

6. Results from a reverse-bending cantilever-type machine show reasonably good correlation with shock data

7. Results show that materials which have relatively high endurance values also have relatively high plastic deformations each loading cycle.

When tests which primarily measure energy absorption are compared with those which primarily measure ultimate supported load, it appears that tests of the former variety most nearly correlate with ability to withstand mechanical shock. The Charpy and Izod tests are in the energy absorption category. Rotating-beam or cantilever-bending tests fall approximately into this category when a large, constant, strain-amplitude is used, but not when a constant load is applied. More restrictions would have to be ap-

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K Series K2R Series	Maximum Torque Inch Pounds Continuous Load	Hand Operation
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K-2-A	350	5,000
L6S Series L6N Series	400	2,000

	Recommended Torque Rating, Inch Pounds	Needle Bearings
L10S Series	650	Optional
1FR Series	1,080	"
L14S Series	1,230	"
3DR Series	1,800	"
L16S Series	2,200	"
35N Series	10,000	"

N Series	Recommended Torque Rating, Inch Pounds	Balanced for
45N	14,000	3600 R.P.M. Max.
5N	20,000	"
50N	20,000	"
6N	38,000	"
60N	38,000	"
7N	57,000	"
70N	57,000	"
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BW Series	Maximum Torque Inch Pounds Continuous Load	Momentary Load
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BW-1	1,695	7,500
BW-2	3,350	11,720
BW-3	4,450	16,800
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For details, contact Blood Brothers, stating your specific problem. We'll be glad to cooperate with engineering suggestions.

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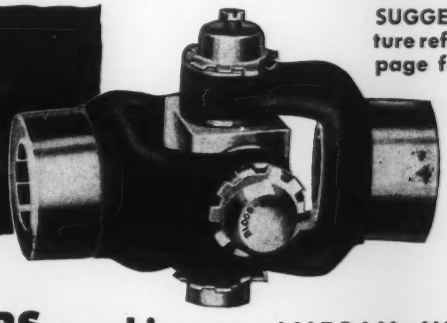

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The Clarkson Manufacturing Co., Nashville, Illinois
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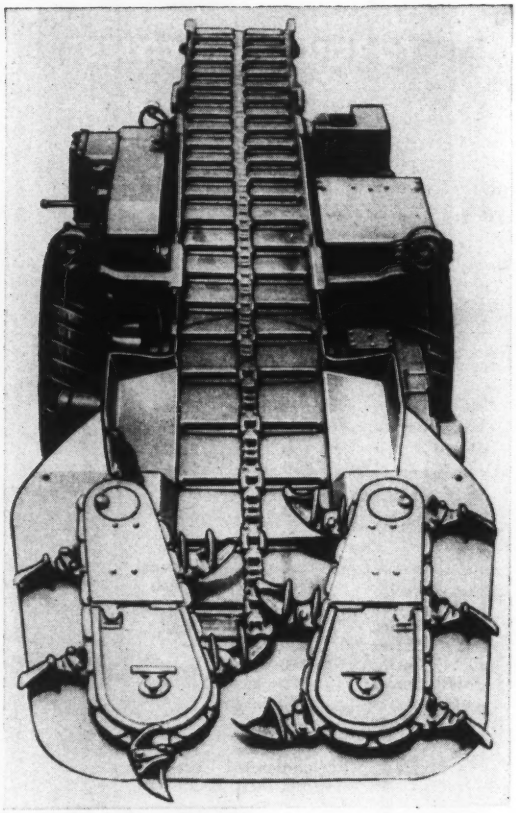
John L. Clarkson



CLARKSON UNDERGROUND LOADING MACHINE

This machine, widely used in the coal mines, has its vital hydraulic power system protected by the Marvel Synclinal filter. Like over 270 other manufacturers, The Clarkson Manufacturing Company installs Marvel Synclinal filters as original equipment.

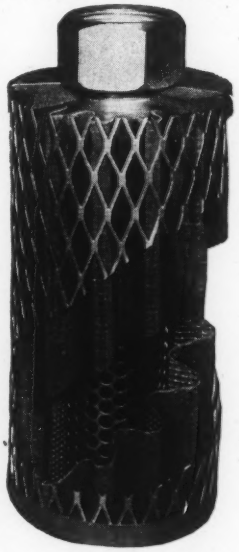
INCREASE PRODUCTION
REDUCE MAINTENANCE COST

Protect Hydraulic Equipment with Marvel Synclinal Filters

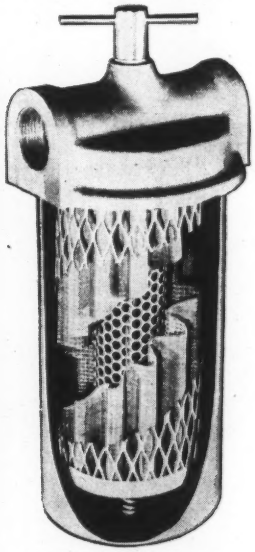
More and more manufacturers and users of hydraulic machines and other equipment with low pressure, non-corrosive liquid systems are depending on Marvel Synclinal Filters to protect their machines' efficiency. Marvel Synclinal Filters are speeding production in a wide range of industries. They offer longer periods of operation between cleanings plus simplicity which enables ordinary workmen to quickly disassemble, clean and reassemble the filter on the spot. Turning a single handnut releases line model for cleaning without disturbing pipe connections.

5 TO 100 G.P.M. SIZES IN SUMP AND LINE TYPES

Both models are available in mesh sizes from 30 to 200. For efficient filtration of non-corrosive liquids in all hydraulic and low pressure systems, Marvel has the right filter protection for your machine.



SUMP TYPE (Cutaway)



LINE TYPE (Cutaway)

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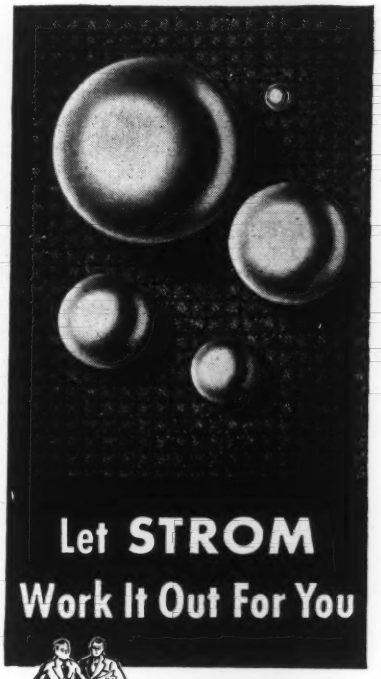
a metal ball PROBLEM?



Whether it is a precision ball bearing or one of the other many ball applications in industry, your problem will not be entirely new. Strom has been in on many ball problems and knows the importance of the right ball for the job.

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plied to those generalizations for materials that are very sensitive to temperature, strain rates, stress-concentration factors, and size effects.

Data indicate that none of the common physical tests give a reliable indication of shock resistance. Shock resistance can, at the present time, be determined most reliably by a dynamic test which simulates field conditions.

The following tentative conclusions have been reached:

1. Selection of materials to withstand severe mechanical shock conditions should be based on actual service tests. In the case of cast materials, precautions are required to insure that material in test specimens is representative of that in castings

2. Ductility and ability to absorb energy are the most significant factors in determining resistance of materials to repeated mechanical shocks of the type used here. However, the ductility obtained from static tests may not be the same as dynamic values where reversals of loads or repeated loads are involved. It was found that materials having the highest energy absorption before fracture also had the highest shock resistance.

3. Shock resistance, as well as other mechanical properties, shown by this and a previous report, depend to a great extent on melting, casting, and other procedures used in fabrication. Therefore, relative resistance of the alloys given by these data may not necessarily be applicable to other sets of specimens of the same alloys. Compliance with physical requirements provided in the material specifications may still permit wide variations in strength for resisting shock

4. All specimens with maximum stressed areas in the as-cast condition were more shock resistant than corresponding specimens cast 75 per cent oversize and machined to proper dimensions. The effect of varying the relative amount of material removed has not been studied; however, results indicate that designs involving deep machining should be avoided.

Further research on the properties which influence shock resistance of materials should include more fundamental studies of materials which have been fabricated under close control.

From report PS 105 301, *"Resistance of Materials to Mechanical Shock," prepared by the Naval Research Laboratory, Washington, D. C.*

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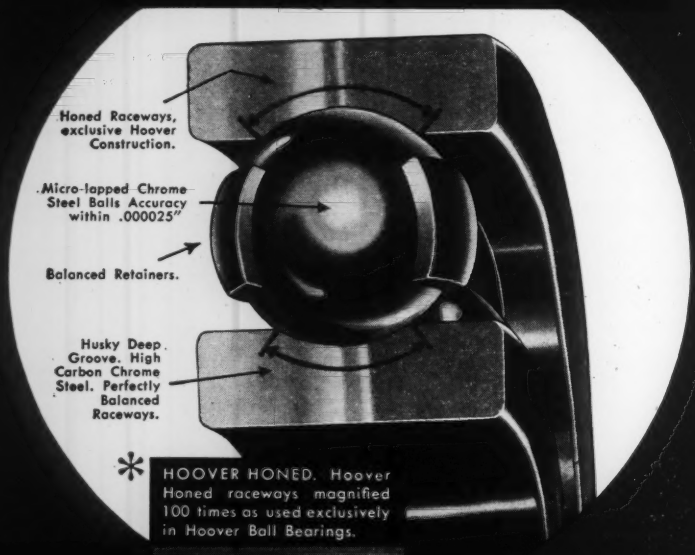
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News

OF MANUFACTURERS

THIS FALL, **Hotpoint Inc.**, Chicago, will begin retooling its defense factory for production of refrigerators. Pilot runs are scheduled for June, 1953. The present defense factory, containing approximately one million sq ft of manufacturing space, is currently producing jet engine components for the United States Navy. At the request of the Navy, Hotpoint will continue to manufacture jet components permanently in this factory, although the bulk of the manufacturing space will be made available for refrigerator output.

♦

A plant comprised of two 90 by 400-ft structures is being built for the **S. Morgan Smith Co.**, York, Pa., as the first step in the company's expansion program. Approximately 100,000 sq ft of working space will be provided in the new plant, which is scheduled to be in operation within a year.

♦

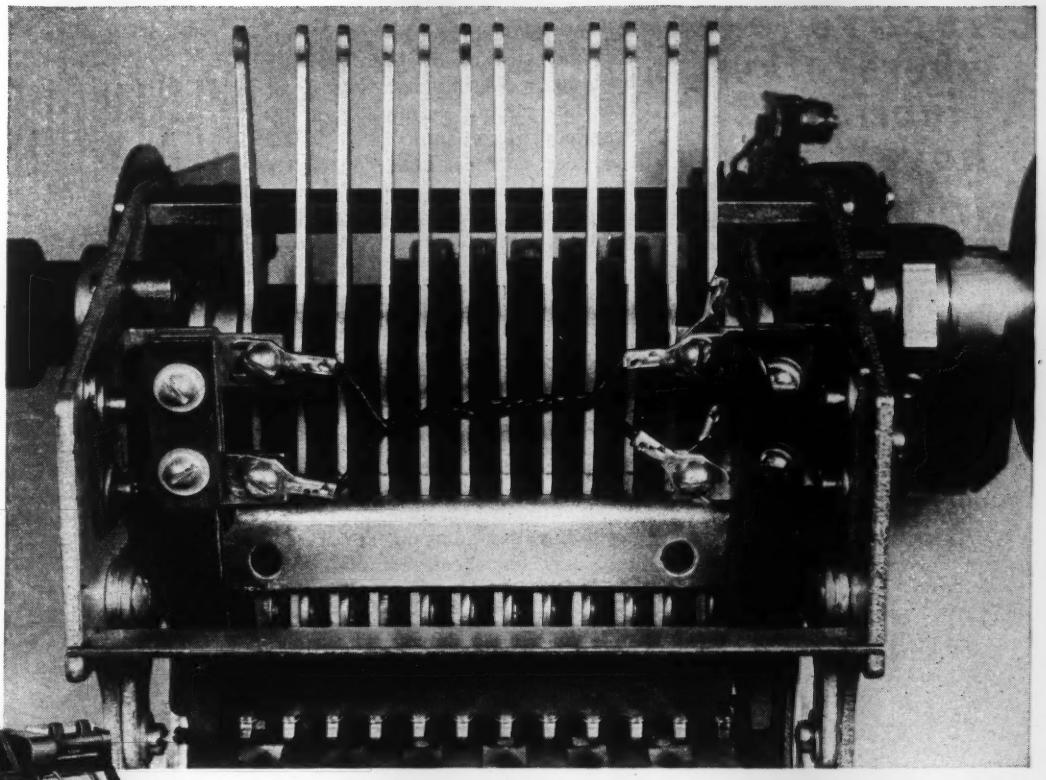
The research laboratory of **The DoAll Co.** was recently moved into new, enlarged quarters at 254 North Laurel Ave., Des Plains, Ill. The laboratory's staff has been working out problems in band sawing and band filing for all types of low-speed, high-speed and friction cutting equipment. A new department for research in all phases of surface grinding application has been added to the laboratory.

♦

A corporate change has taken place in the Vonnegut Moulder Corp., Indianapolis, as a result of the retirement of Anton Vonnegut. The business, taken over by present personnel, will henceforth be known as the **Grinding and Polishing Machinery Corp.**

♦

Three new buildings have been added to the transformer and allied products division facilities of **General Electric Co.** at Pittsfield, Mass. Operations in the new buildings include manufacture of laminated cylinders for insulating



IBM punch magnet assembly, showing felt spacers

IBM Card Punch, made by International Business Machines Corporation, New York 22, N. Y.

Felt Functions For IBM

It is important to remember that felt often can do several things at the same time. Here is an example in which felt, American Felt, is used as a spacer, a source of lubricant, and a lubricant control. The machine is an IBM Card Punch, used to punch accounting cards rapidly, accurately, and cleanly. The felt spacers are used in the punch magnet assembly, at the point where the operating arms pivot to actuate the punches. The spacers are impregnated with oil, thus providing an ample and long-lasting source of lubrication at the exact points where wear or corrosion might occur between the fast-moving arms and the shaft. Another virtue of the felt is control; it eliminates the possibility of oil dropping down into the circuit breakers beneath the unit. Other IBM machines of various types likewise use American Felt. There are some 16 chief mechanical functions for which American Felt is used, plus many subsidiary ones. It will pay you to investigate what American Felt can do for you in your plant or product. See the nearest Sales Office or write direct.

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Effective even where other lubricants have failed

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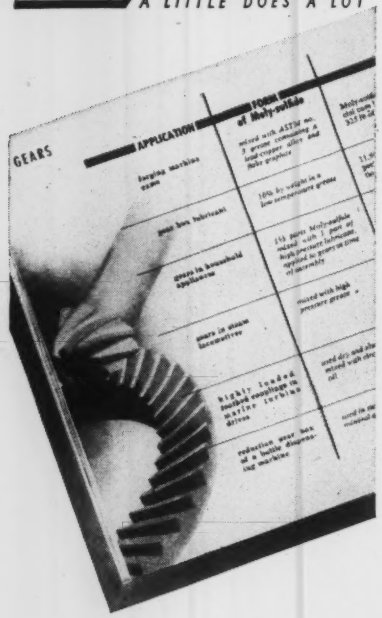

Moly-sulfide, a solid film lubricant, stands out most where the lubricating conditions are the most difficult. If you have to contend with extreme conditions of pressure, temperature, fretting, or velocity, you should try *Moly-sulfide*. First write for a copy of this free 40-page booklet which shows where the above conditions have already been overcome in the shop and in the field.

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transformer coils, production of copper conductors for transformers and testing of high voltage bushings. An unusual feature of the tube rolling building is a hydraulic stripper sunk 28 ft below the floor surface, used to remove the completed cylinders from the steel mandrels on which they are wound.

♦

According to a recent announcement, Hydraulic Equipment Co., Cleveland, is now operating as **Hydreco**, a division of **The New York Air Brake Co.**, instead of as a subsidiary of that company.

♦

An extensive expansion program, including the addition of another building, has been completed by **Paper Machinery and Research Inc.**, Roselle, N. J. The expansion program also included several new lathes and engraving machines and a dynamic balancing machine reported to be one of the largest in the East.

♦

To support an extensive development program in industrial valves, the **Valve Div.** of **Minnneapolis-Honeywell Regulator Co.**, Minneapolis, has established a research center in Philadelphia. Test and research equipment has been provided to evaluate present valve design and performance and to carry out research into new valve types to parallel advances being made in modern process control. A hydraulic laboratory is built into the research center to measure valve capacity and the static and dynamic internal forces of valves. An important phase of the research activity will be determining the suitability of substitute valve materials proposed to relieve the critical alloy situation.

♦

Loewy Construction Co. Inc., a subsidiary of **Hydropress Inc.**, New York, will supply two die forging presses and six extrusion presses, together with the required hydraulic power plants, for the heavy press program of the U. S. Air Force. Two die forging presses, one of 50,000 tons and the other of 35,000 tons capacity will be operated by the **Wyman-Gordon Co.**,

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This Westward-Ho early American pressed glass compote depicts a log cabin, the early American home. The bison and deer, food. The crouched Indian, falling back, giving way to progress and world leadership.

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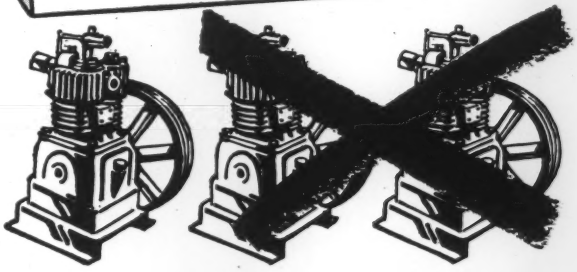
plans are on the way [illegible]
expect to have them ready for you.

The synthetic cup packings which we have obtained from you are truly doing a fine job, and while previously we needed three compressors going almost continually to take care of the leaks in our presses, one compressor is now handling the entire job with ease. We wish that all problems could be cured up as satisfactorily as this packings problem.

Very truly yours,



One compressor does the job now

One morning a few months ago the phone rang . . . "Can you send someone over right away? . . . our presses are leaking air . . . three compressors can't keep them operating right . . . need new 6" cup packings . . ."

The I.P.C. engineer who responded examined the pneumatic cylinders. It was apparent that, at 100 psi, the conditions of operation would be particularly destructive to the type of material being used for cup packings in these cylinders. He recommended a special cup packing for which we had tools available, and which had been proved by performance in a similar operation.

Next day the cups were installed — and now one air compressor is handling the entire battery of cylinders with ease.

We, too, wish that all packings problems could be solved so easily. Some are. When the specs call for standard packings types we can furnish them in leather or rubber to JIC standards. When the job calls for something special, give us the information in detail. We'll try to come up with the answer — perhaps a new design; in any case a material that is best for *all* your conditions; and *always* service you can depend upon.

FREE
NEW O-RING BOOKLET

16 pages of illustrations, application data and specification charts, Shows what and how to order if you wish the most efficient application to your own installation. Write for your copy.

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Leather and synthetic packings

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Worcester 4, Mass.

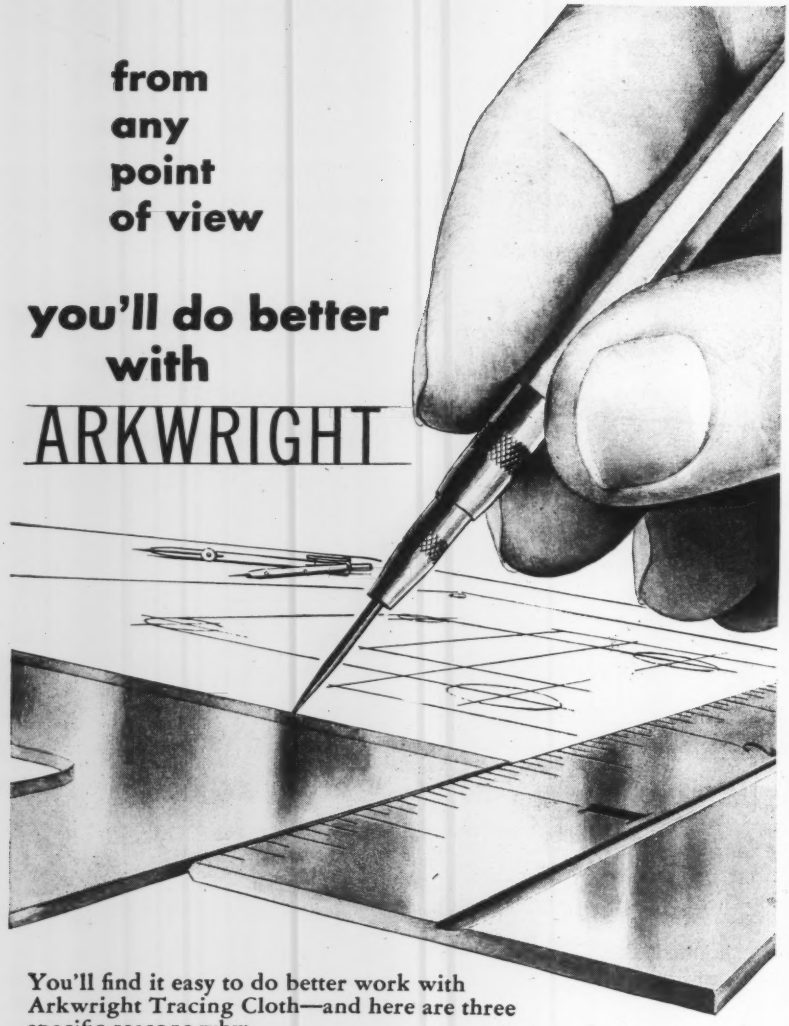
IPC

Address correspondence to
INTERNATIONAL PACKINGS CORPORATION
Bristol, New Hampshire

from any point of view

you'll do better with

ARKWRIGHT



You'll find it easy to do better work with Arkwright Tracing Cloth—and here are three specific reasons why:

1 You can re-ink razor-sharp lines over any erasure without "feathering" or "blobbing".

2 You're never slowed down by pinholes, uneven yarns or other imperfections.

3 You can always count on clean, clear reproduction—even years after you make the drawing. Arkwright Tracing Cloth is *permanently* transparent—won't turn opaque, brittle or paper-frayed with age.

They're important reasons for putting *your* best work on Arkwright Tracing Cloth. Like a sample? Write Arkwright Finishing Co., Industrial Trust Bldg., Providence, R. I.

ARKWRIGHT

Tracing Cloths

AMERICA'S STANDARD FOR OVER 30 YEARS

Worcester, Mass. Power plant capacity of these presses will amount to more than 10,500 horsepower. Extrusion presses on order are one of 20,000 tons capacity to be operated by the **Aluminum Co. of America,** Lafayette, Ind.; one of 12,000 tons for operation by **Curtiss-Wright Corp.,** Caldwell, N. J.; two of 8000 tons each for the **Kaiser Aluminum & Chemical Corp.,** Halethorpe, Md.; and two of 8000 tons capacity for operation by **Reynolds Metals Co.,** Phoenix, Ariz., and **The Harvey Machine Co. Inc.,** Torrance, Calif.

♦

A $6,000,000 steam and gas turbine development laboratory will be constructed at the South Philadelphia works of the **Westinghouse Electric Corp.,** Pittsburgh. Initially, special research for the United States Air Force will be conducted at the laboratory, which should be completed in about a year.

♦

Offices of the **Babcock & Wilcox Co.** have been moved to the recently completed Chrysler Building East at 161 East 42nd St., New York City.

♦

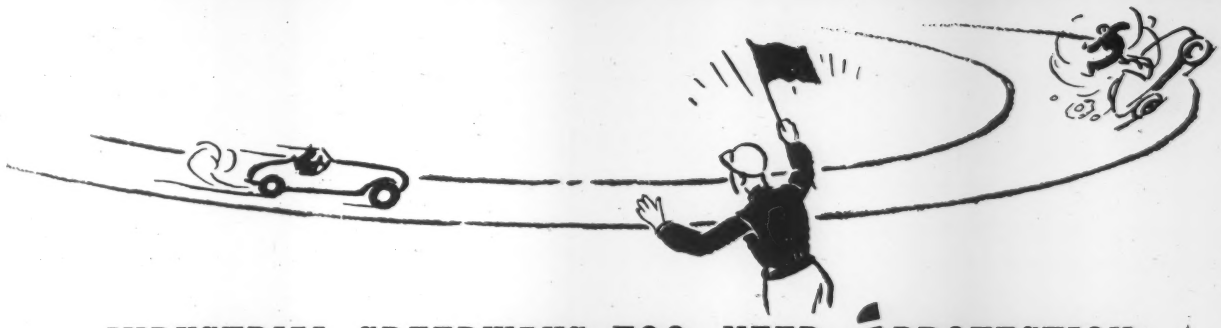
As part of an expansion program undertaken by **Famco Machine Co.,** a new plant and office facilities have been purchased at Kenosha, Wis. The new buildings add approximately 40,000 sq ft of floor space to the company's operation and replace two former plants located in Racine, Wis.

♦

Operations of the Arcade Mfg. Div. of Rockwell Mfg. Co. have been moved to Tupelo, Miss.; it is now known as the **Rockwell Mfg. Co., Tupelo Div.**

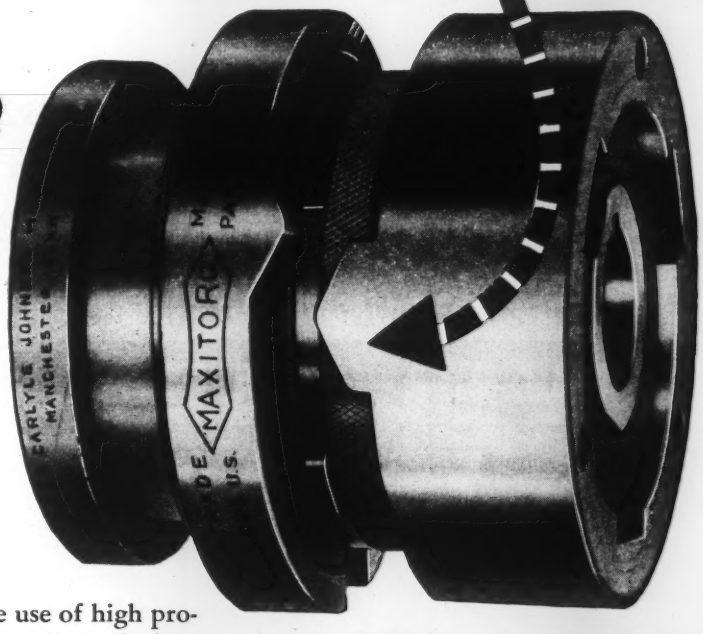
♦

To help assure a steady supply of steel and also to make possible the control of steel quality to exact requirements, two new 18-ton capacity electric steel melting furnaces will be installed in the Chicago plant of Ingersoll Products Div. of **Borg-Warner Corp.** The building being erected to house these furnaces is nearly completed, according to a recent announcement from Borg-Warner. It is estimated that 240 tons of steel a day can be poured from the furnaces.



INDUSTRIAL SPEEDWAYS, TOO, NEED PROTECTION

MAXITORQ
automatic
OVERLOAD RELEASE CLUTCH



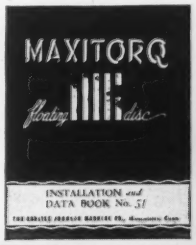
The tremendous expansion in the use of high production automatic machinery, especially in the bottling, packaging, labeling, wrapping and kindred fields, calls for added protection thru safety controls in power transmission equipment.

For this purpose we offer the Maxitorq floating disc Overload Release Clutch which automatically and instantly releases when the nature of an overload is either a heavy shock or suddenly applied load of a magnitude substantially greater than normal driving load. In such instances the machine mechanism may be clogged, products damaged and operator injured...all of which means expensive down-time.

The Overload Release Clutch performs most effectively and prevents heavy overload destruction. When jammed condition is cleared the clutch is re-engaged and operation continues. Simple fingertip adjustment sets the clutch to transmit normal running load. For original equipment, specify Maxitorq. There are six standard capacities, ¼ to 5 H.P. @ 100 r.p.m.

New catalog gives complete engineering specifications; shows complete line of standard clutches and driving cups.

ASK FOR CATALOG No. MD7



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Association
ACTIVITIES

ANNOUNCEMENT has been made by the **Gray Iron Founders' Society** of the opening of its 1952 Redesign Contest. Cash awards in the amount of $500 will be presented for the best example of redesign of a competitive product for gray iron. The contest is open to anyone in the metalworking field and is intended to encourage wider use of gray iron by recognizing designers and others who have successfully used this material. Awards will be made at the Society's annual meeting in October in Cleveland, O. Further details may be obtained from W. M. Caldwell, Gray Iron Founders' Society Inc., 210 National City-E. 6th Bldg., Cleveland 14, O.

♦

One of the most distinguished awards in engineering, the 1953 *John Fritz Medal* and certificate, will be presented to Benjamin F. Fairless, president of the United States Steel Corp., for "... notable industrial achievement in the production of steel." Sponsored jointly by the **American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers** and **American Institute of Electrical Engineers,** the award will be made at the Centennial meeting of the ASCE in Chicago in September.

♦

American Society for Testing Materials has announced the appointment of Robert J. Painter as new treasurer of the Society. He succeeds John K. Rittenhouse, who has retired after 43 years of service. It was also announced that Dorothy P. Douty would be assistant treasurer.

♦

New officers of the **American Gear Manufacturers' Association,** elected at the Association's 36th Annual Meeting in Hot Springs, Va., are: president, S. L. Crawshaw, Western Gear Works; vice president, George H. Sanborn, Fel-

FREE Cylinder Catalog and Templates offered by Ortman-Miller Co.

Book outlines several special features of O-M cylinders.

FREE

A new, 28 page catalog has just been released by the Ortman-Miller Machine Co. which gives complete engineering specifications, data on O-M's special internal locking system and special full listing of O-M parts. Prepared for designers and users of cylinders for any application, it covers standard, oversize and 2-1 piston rods, giving full information on all sizes from 1½" to 8" bores.

SPECIAL FEATURES

Included are detailed explanations of the many features which have made ORTMAN-MILLER cylinders standard in thousands of plants throughout the country. Detailed drawings and copy explain the special shear bar assembly which completely eliminates bulky end caps and tie rods, thus saving up to ⅓ in space. In addition, it shows the vast number of interchangeable mountings and applications which almost always eliminate the need for special castings or patterns. This feature alone not only saves initial costs, but cuts down on inventory and greatly speeds up delivery on every order.

Special Note:

30 DAY DELIVERY

Increased production facilities and standardization of parts continue to make possible delivery in 30 days or less on almost all orders for O-M cylinders. Write today for details.

FREE TEMPLATES

In addition to the FREE catalog, Ortman-Miller also leads the field in making available FREE TEMPLATES of all O-M cylinders. Prepared in half scale, they are extremely useful in design and application of O-M cylinders to your special requirements.

For your FREE Catalog or templates, use the coupon in the ad at the right. Or write to ORTMAN-MILLER Machine Co., 1210 150th St., Hammond, Indiana.

4

YOU O-M CYLINDERS

1 30 DAY DELIVERY

Complete standardization of interchangeable parts and elimination of need for special patterns and castings mean faster production, lower costs. Even the most difficult "custom" applications can almost always be made from O-M standard cylinders . . . without delay!

2 NO TIE-RODS, BOLTS or SCREWS!

New simplified design completely eliminates bulky end caps and tie rods, saves up to ⅓ in space. No bolts or screws. Special circumferential keys allow quick, easy installation, even faster repacking.

3 MACHINED STEEL, NO CASTINGS

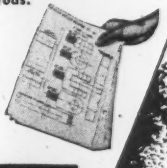
All cylinder body parts are bar stock steel, made in automatic screw machines. No castings whatsoever. All bearing surfaces are bronze.

4 SAVE SPACE, TIME AND MONEY

O-M special features mean less inventory . . . increased uses from standard sizes. Interchangeable mounting brackets, ports adjustable to any angle. Full range of sizes from 1½" to 8" bores.

FREE!

NEW CATALOG
Gives full details, data and specifications on all O-M cylinders. Standard, oversize & 2-1 piston rods.



TEMPLATES
Complete set of ½ scale templates showing all cylinders and mounting brackets.

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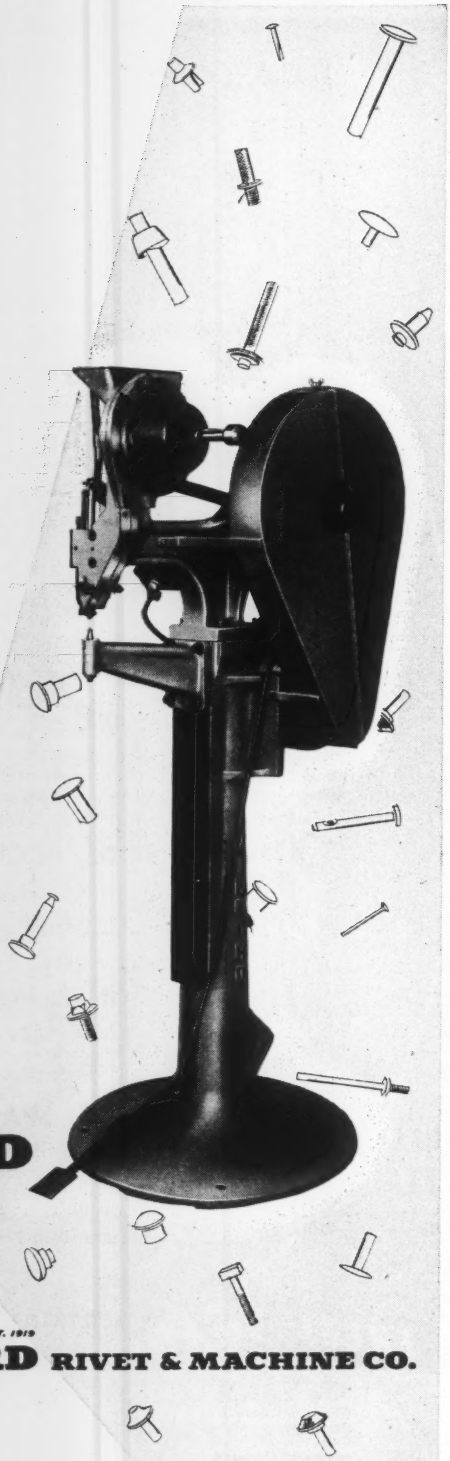
Speedier assembly . . . better appearance . . . fewer rejects . . . greater strength . . quantity runs?
Whatever your choice, you will benefit by investigating THE MILFORD METHOD, an integrated service of fastener research, design, engineering, and production collaboration.

Give wings to work . . . use rivets and rivet-setters identified by the flying "M" trade mark . . . a symbol of quality for quality products of metal, leather, cloth, plastic, wood and paper. With an eye to the future, inquire about THE MILFORD METHOD to-day!



MILFORD
the name to rivet in your memory for fasteners

the MILFORD EST. 1919 RIVET & MACHINE CO.

MILFORD, CONN., 869 Bridgeport Avenue

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ELYRIA, O., 1108 W. River Street

HATBORO, PA., 28 Platt Street

lows Gear Shaper Co.; and treasurer, R. B. Holmes, Link-Belt Co. Elected to membership on the executive committee were R. C. Wilson, Farrel - Birmingham Buffalo Div.; Charles Everett Stine, Ferguson Gear Co.; L. J. Collins, General Electric Co.; and Ervin F. Borisch, Milwaukee Gear Co.

♦

Student awards will be added to this year's Methods Improvement Competition sponsored by the **Industrial Management Society.** Student groups studying industrial engineering as well as industrial plants and companies are invited to submit entries. Special Achievement Awards will be presented at the Society's 16th Annual Clinic scheduled for November 5, 6 and 7 in Chicago. Rules and regulations for the competition may be obtained by writing the Industrial Management Society, 35 E. Wacker Dr., Chicago 1, Ill.

♦

William E. Cramer, Industrial Ceramic Products Inc., new president of **The American Ceramic Society,** took office at the 54th Annual Meeting held in Pittsburgh, April 27-May 1. Other officers installed at the meeting included president elect, R. R. Danielson, Metal and Thermit Corp; vice presidents, Victor C. Swicker, Alexander H. Kerr & Co. Inc., Harry H. Holscher, Owens-Illinois Glass Co., H. B. DuBois, Consolidated Feldspar Corp.; and treasurer, Edwin M. Rupp, sales engineer. Charles S. Pearce, general secretary of the Society, is starting his eighth year in that office.

♦

F. R. Dickenson, Townsend Co., is the newly elected vice president of the **Industrial Fasteners Institute.** This office is the highest elective position in the Institute held by an active manufacturer.

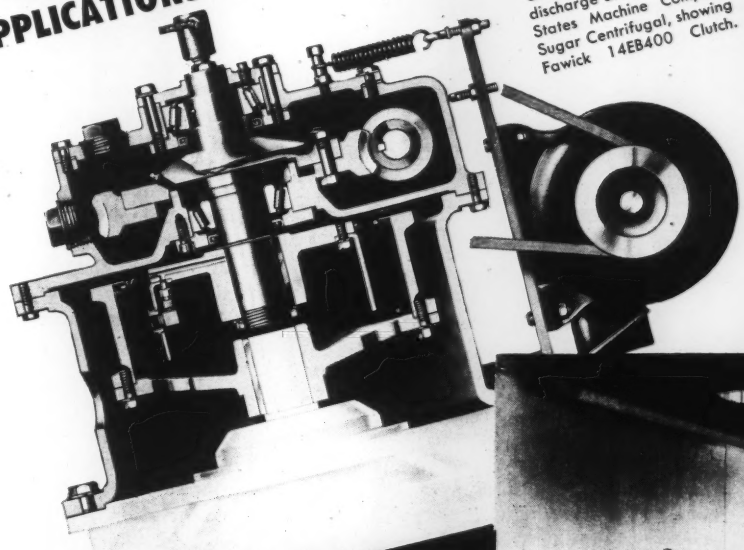
♦

The **American Iron and Steel Institute,** at recent meetings in New York, made the following awards:

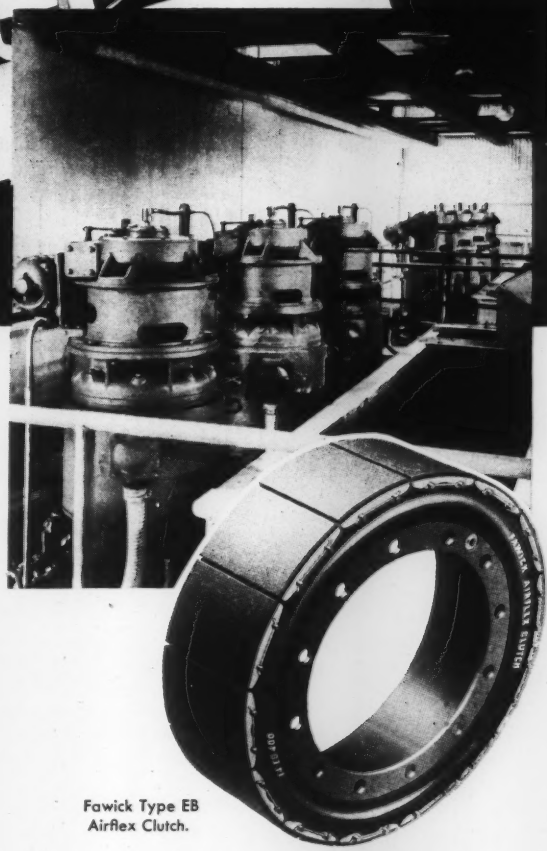
Gary Memorial Medal to Walter S. Tower, retiring president of the Institute, for outstanding achievement in the industry.

Regional Technical Meeting Award to L. F. Reinartz, Armco Steel Corp., for the paper of out-

TYPICAL EXAMPLE OF FAWICK CLUTCH APPLICATIONS IN THE SUGAR INDUSTRY



Cross section of slow speed discharge drive of Western States Machine Company Sugar Centrifugal, showing Fawick 14EB400 Clutch.



Fawick Type EB Airflex Clutch.

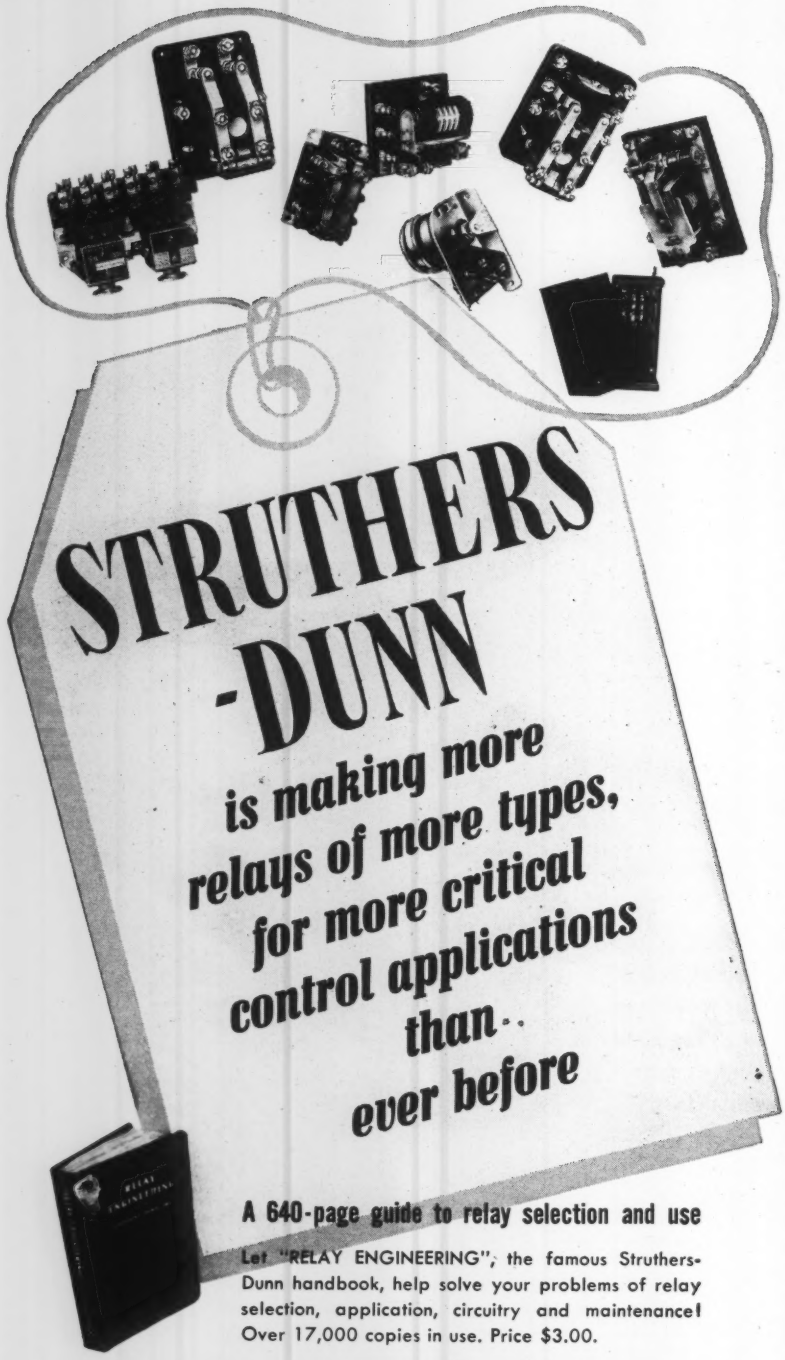
In choosing a clutch for the slow speed discharge drive of their Sugar Centrifugal, the Western States Machine Company chose FAWICK because of its adaptability to the compact design required for the drive. The self-adjusting, maintenance-free FAWICK UNIT makes it possible for the clutch to be mounted in a location where repetitive servicing and lubrication would be difficult.

This slow speed drive of the Centrifugal is used in plowing the sugar from the basket after the fluid has been removed by centrifugal separation. The complete disengagement characteristic of the FAWICK CLUTCH insures the dependable free-running of the main drive motor and basket during the spinning cycle. You too will find in FAWICK UNITS the reliable, performance-proved characteristics needed in your machine operation.

The FAWICK AIRFLEX COMPANY, Inc.
9919 CLINTON ROAD • CLEVELAND 11, OHIO

For further information on Fawick Industrial Clutch and Brake Units, write to the Main Office, Cleveland, Ohio, for Bulletin ML-22.

FAWICK Airflex
INDUSTRIAL CLUTCHES AND BRAKES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ST. LOUIS • SAN FRANCISCO • SEATTLE • SYRACUSE • TORONTO

standing merit in regional programs of the previous year.

American Iron and Steel Institute Medal to John S. Marsh, Bethlehem Steel Co., for a paper of special merit in connection with the activities of the iron and steel industry.

♦

New officers elected at the Annual Meeting of the **American Society of Lubrication Engineers** are: president, M. E. Merchant, Cincinnati Milling Machine Co.; vice president at large, W. E. Campbell, Bell Telephone Laboratories; secretary-treasurer, W. H. Fowler Jr., Pure Oil Co.; and administrative secretary, W. P. Youngclaus Jr., Stewart Warner Corp.

♦

In recognition of a half century of continuous and outstanding service in the electrical industry, the board of governors of the **National Electrical Manufacturers' Association** recently awarded Carl E. Johnson, board chairman of Sterling Electric Motors Inc., with its *Fifty-Year Certificate.*

♦

Simon Collier, Johns-Manville Corp., has been elected president of the **American Society for Quality Control** at the Society's sixth convention in Syracuse, N. Y. Also, newly elected as vice presidents were: Raymond S. Saddoris, A. O. Smith Corp.; Dr. Julian H. Toulouse, Owens-Illinois Glass Co.; and Arthur Bender Jr., General Motors Corp. The new executive secretary is Edward B. Haden, Esterbrook Pen Co. Paul A. Robert, International Business Machines Corp., remains as treasurer.

♦

Results of their Second Annual National Scholarship Contest have been announced by the **American Society of Tool Engineers.** Scholarship awards of $300 each—based on scholastic standing, faculty recommendations, and interest shown in furthering tool engineering — have been presented to Merton L. Bartsch, University of Minnesota; Hearst McClellan, University of Cincinnati; Raymond F. Perner, University of Texas; and David Lee Poli, Ohio State University. A fifth award will be made later to a Canadian student tool engineer.

BOLTS
Aircraft
Battery
Bicycle
Carriage
Connecting Rod
Cylinder Head
Dardelet
Elevator
Fitting-up & Boiler
Furniture
Hanger
Key
Lag
License Plate
Machine
Plier
Plow-cultivator
Ribbed
Sheathing
Skein
Spring Center
Step
Stove
Stud
Tire
Track
"U," "J," Eye & Hook
Weather Tight
Wheel

NUTS
Acorn
Aircraft
Castellated
Cold-forged
Cold punched
Hot pressed
Lamson Lock Nuts
Machine Screw (square & hex)
Marsden
Semi-finished
Weld

PINS
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Clutch Head
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Phillips Head
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Flat Spring Keys
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Inserts, plastic
Lok-thred Studs
Pipe Plugs
Place Bolts
Plug Nuts
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Sems
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Tinners Rivets
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Wire Rope Clips
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Many of these products are available in Carbon and Alloy Steel, Brass, Bronze, Stainless Steel, Monel Metal and Aluminum Alloys.
Finishes: Pentrate Black • Cadmium • Chromium • Electro-galvanized • Dichromate and Parkerized

this is what we mean by "the COMPLETE LAMSON LINE"

The home of "quality controlled" fasteners

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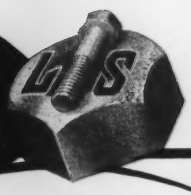

The LAMSON & SESSIONS Co.
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Plants at Cleveland and Kent, Ohio • Birmingham • Chicago

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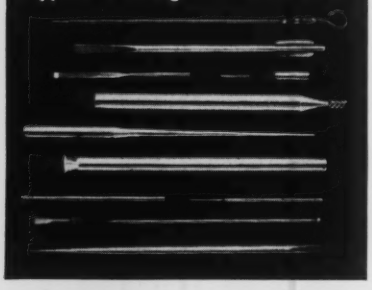
"Joe, getting small metal parts with precision tolerances is always a problem."

"Not when we have Torrington make them, Tom. Their production methods and facilities are among the finest in the world."

The methods used by our Specialty Department in the production of precision metal parts are the result of over 86 years of constant effort to decrease the cost and improve the quality of our own products. Most operations are performed on automatic and semi-automatic machines – many of them Torrington-designed – that assure uniform quality and precision. The latest heat-treating and finishing practices give proper temper and hardness. And mass-production techniques make possible the greatest possible economy on any quantity of small metal components.

If *you* need precision metal parts, ask us for a quotation. Just send us a blueprint or sample and tell us how many you need. The low cost will surprise you!

Typical Torrington-Made Parts



THE TORRINGTON COMPANY
Specialty Department
553 Field Street • Torrington, Conn.
Makers of
TORRINGTON NEEDLE BEARINGS

SALES AND SERVICE

Personnel

NEW sales managers have been appointed for the Philadelphia and Colmar, Pa., plants of Link-Belt Co., Chicago. **James H. Oakes,** former sales manager for enclosed drives, will be in charge at Philadelphia, and **Byron K. Hartman,** former assistant sales manager at Philadelphia, will go to the new Colmar plant, which is scheduled to begin manufacturing operations later this year.

♦

Norbert Beerli has joined The Paquin Co., Cleveland, as hydraulic engineer to assist in applying the company's products to customers' machines and hydraulic installations.

♦

Two new district representatives were appointed recently by C. A. Norgren Co., Englewood, Colo. **Ted W. Sess** was named a district representative in southern California to handle pneumatic product sales along with the district representative already operating in the area. **A. Louis Hacker** has been appointed district representative for Maryland and Washington, D. C.

♦

O. B. Wilson has been made field sales manager for the industrial division of Minneapolis-Honeywell Regulator Co., Minneapolis. He succeeds **William H. Steinkamp,** who was recently made general sales manager of the division. Mr. Wilson will supervise all field sales and service personnel for industrial division products.

♦

Appointment of **Harold H. Burrows** as sales manager of the company's industrial rubber goods sales division has been announced by Raybestos-Manhattan Inc., Passaic, N. J.

♦

Three new field representatives were recently appointed by Milford Rivet & Machine Co., Milford, Conn. **Howland Hayes** and **Robert D. Richter,** who have completed eight months in-plant training at

A PRACTICAL SOLUTION TO THE

TECHNICAL MANPOWER SHORTAGE PROBLEM

Are you interested in the possibility of getting some of your testing and trouble shooting work done without hiring another man?

Our solution is very direct. No doubt many of your trained engineers and chemists are tied down by routine but essential testing tasks. You can release these men for more demanding, more responsible duties (promotions which they would appreciate!) by entrusting our laboratories with your routine testing schedules.

Why is this possible? Because Testing is our Business. Your tests will be handled by men who live, breathe, and think testing. They will receive the care and attention that only a specialized laboratory can give them. That means speed, accuracy, and real economy.

We would like to get together and discuss your manpower problems and possibly point the way to a solution.

Write for booklet describing our services.

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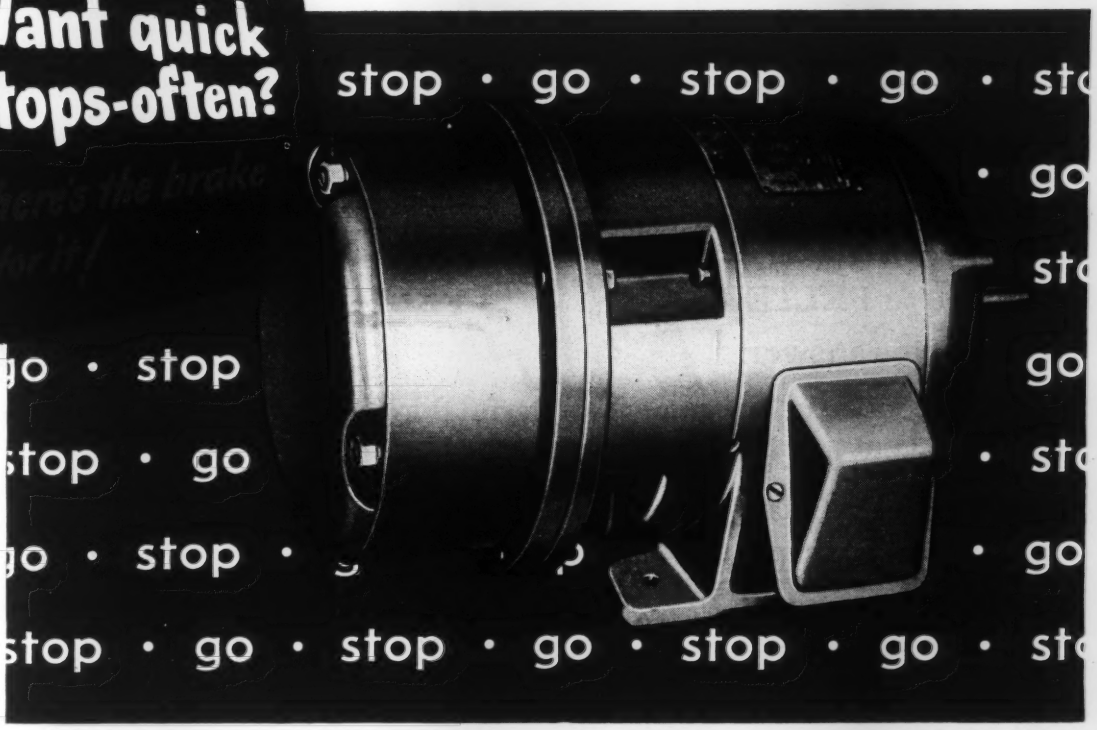
Member of American Council of Commercial Laboratories

Want quick stops-often?



The *ELLIOTT* CROCKER-WHEELER *Brake* MOTOR

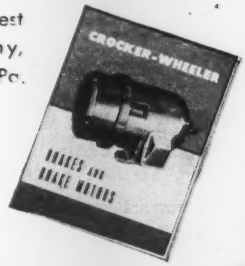
■ The bonded metal brake linings of the C-W brake give greater friction for quicker stops, greater wear resistance, complete immunity to climatic conditions, oil or grease, and long service with no change in retarding torque.

The unusually short overhang of the C-W brake provides maximum rigidity and the compactness that adapts it to limited space — a vital feature on machine drives. The magnetic action which releases the brake is instantaneous and powerful. The entire mechanism is completely enclosed in an easily removable cover.

Here is a brake you can depend upon to do its job day in and day out with true Crocker-Wheeler reliability. Available as part of any C-W integral motor, or separately for mounting on NEMA D flange motors, frames 203-326, or C face motors, frames 364-405.

GET BRAKE MOTOR BULLETIN SL-610-1,

addressing your request to Elliott Company, Dept. MD, Jeannette, Pa.



W2-2

ELLIOTT Company

CROCKER-WHEELER DIVISION
AMPERE, N. J.

For large motors: RIDGWAY DIV., RIDGWAY, PA.
Plants at: JEANNETTE, PA. • RIDGWAY, PA.
AMPERE, N. J. • SPRINGFIELD, O. • NEWARK, N. J.
DISTRICT OFFICES IN PRINCIPAL CITIES
ELLIOTT APPROVED SERVICE SHOPS COVER THE COUNTRY

MATERIAL PROBLEMS GOT YOU DOWN?

Let FELT help you come up with the answer!

Many a designer baffled by material problems has turned to FELTERS FELT and found his answer.

That's because of the many wonderful things that FELT can do... and because of the many amazing things that you can do with FELT

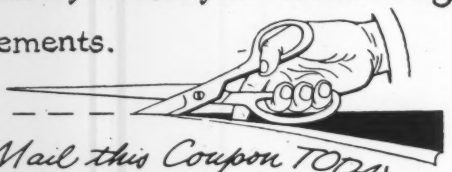
For instance FELT can be subjected to sun, water heat or cold with no harmful effects

Too, you can use it freely in contact with oil, gasoline or other petroleum products.

We can supply you with FELT that is tough enough to grind, chisel, die-cut, turn, scarf or skive

On the other hand we'll make it so soft for you that you can use it to polish the finest optical lens

And we'll supply it promptly and on time in any form you desire by the roll, strip or square yard... or we'll cut it precisely to meet your most exacting size and shape requirements.



Fill out and Mail this Coupon TODAY!

The FELTERS COMPANY

Manufacturers of Unisorb for Machine Mounting

210-MD SOUTH STREET, BOSTON 11, MASS.

Gentlemen: Please send me details on Felters Felt and Felters Precision Cut Felt Parts. I have the following material problem:

.....

.....

Name & Title.....

Company.....

Address.....

City & State.....

DEPARTMENT OF TECHNOLOGY BUFFALO PUBLIC LIBRARY

Milford, will cover northern New Jersey and metropolitan New York, respectively. Mr. Hayes will make his headquarters at 972 Broad St., Newark, N. J.; Mr. Richter, at 40 East 40th St., New York. With headquarters at 19650 Harper Ave., Detroit, **W. T. Peterson** will be responsible for the Michigan district.

♦

John M. Dumser has been named as director of sales of the Wolverine Tube Div. of Calumet and Hecla Consolidated Copper Co., Detroit. This division also recently appointed **John P. Howland** as sales representative in the Dallas area, with headquarters in Room 206, 309 Browder St., Dallas 1, Tex.

♦

Pittsburgh Screw and Bolt Corp., Pittsburgh, has announced the election of **Alexander I. Stayman** to the office of vice president of sales. He has been associated with the company's sales division for 17 years.

♦

James H. Ferguson, former Toledo, O., sales engineer for Strong, Carlisle and Hammond Co., Cleveland, has been promoted to branch manager of the company's new Detroit office located at 18133 James Couzens Highway. **Richard C. Sauber** replaces Mr. Ferguson in Toledo.

♦

Two new sales executives were recently appointed by Russell, Burdsall & Ward Bolt and Nut Co., Port Chester, N. Y. To be located at the company's new sales offices, 2100 First National Bank Bldg., Pittsburgh 22, Pa., **Richard D. Baker** has been named resident vice president, and **Thomas Toby,** assistant manager of sales.

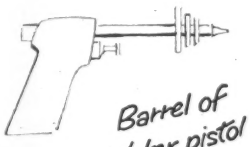
♦

Emmet D. Griffin has retired as vice president in charge of the paint division of Pittsburgh Plate Glass Co., Pittsburgh. He will continue to serve as a member of the board of directors for at least a year and will also function as a general consultant. **E. D. Peck,** general paint manager for the merchandising division of the firm for the past 12 years, has been elected vice president to succeed Mr. Griffin. Mr. Peck has been

Bundyweld "Doodles"

to jog a designer's imagination

Frame of popular laundry hamper



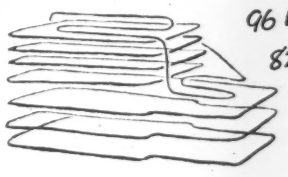
Barrel of Water pistol

Redesigning an old product? Developing a new one? With Bundyweld Tubing on the job, there's every chance for improved performance, lowered cost, smoother production, *or* some other practical plus.

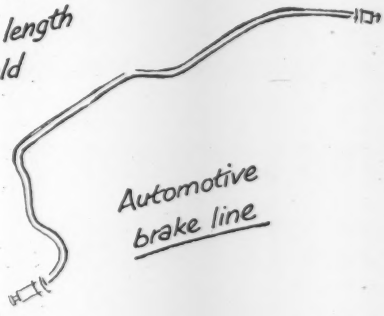
No other tubing has all the Bundyweld features. It's the only tubing double-walled from a single strip, with inside and outside beveled edges.

Too, you may profit from Bundy's famous fabrication skills. In working out tubing parts like those shown here, we may have found the answer to something baffling you. Or we can develop a new solution. Let us send you information on Bundyweld Tubing or Bundy services. ***Bundy Tubing Company, Detroit 14, Michigan.***

Coil for a Home Freezer



96 bends — 82' continuous length of Bundyweld



Automotive brake line

Bundyweld® Tubing

DOUBLE-WALLED FROM A SINGLE STRIP

Extra-strong
High fatigue limit
Leakproof
High bursting point
High thermal conductivity
Shock-resistant
Ductile

Easily machined
Takes plating
Takes plastic coating
Scale-free
Clean inside and out
No inside bead
Uniform I.D., O.D.

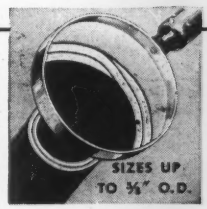
WHY BUNDYWELD IS BETTER TUBING

Bundyweld starts as a single strip of copper-coated steel. Then it's . . .

continuously rolled twice around laterally into a tube of uniform thickness, and

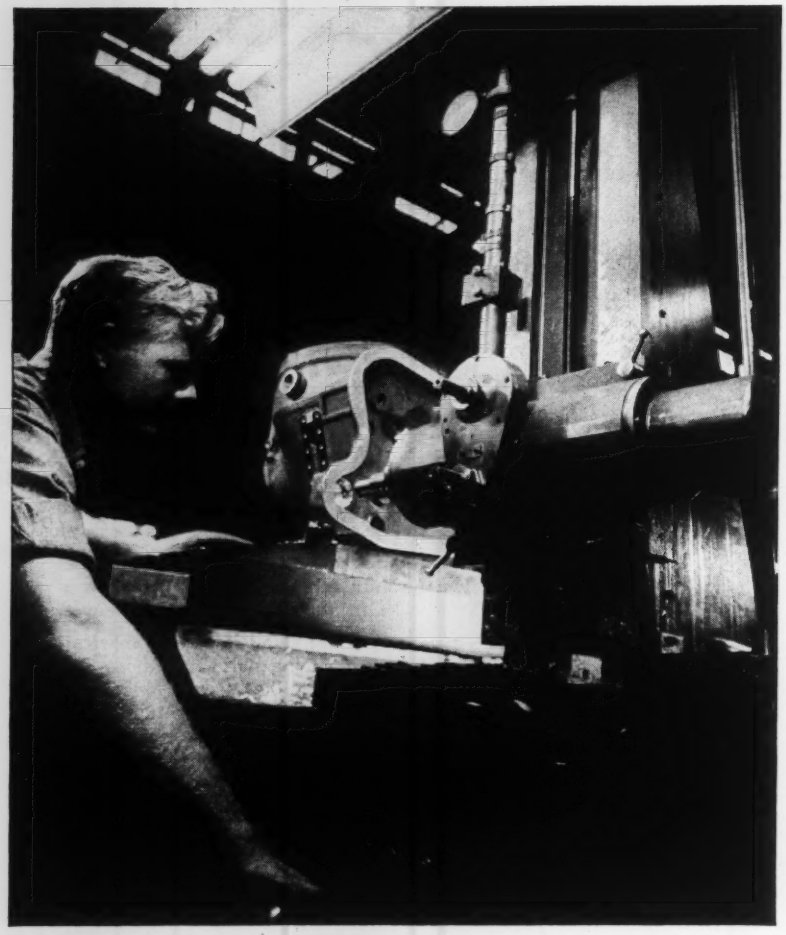
passed through a furnace. Copper coating fuses with steel. Presto . . .

Bundyweld, double-walled and brazed through 360° of wall contact.



← **NOTE** the exclusive patented Bundyweld beveled edges, which afford a smoother joint, absence of bead and less chance for any leakage.

Bundy Tubing Distributors and Representatives: ***Cambridge, 42, Mass.:*** Austin-Hastings Co., Inc., 226 Binney St. • ***Chattanooga 2, Tenn.:*** Peirson-Deakins Co., 823-824 Chattanooga Bank Bldg. • ***Chicago 32, Ill.:*** Lapham-Hickey Co., 3333 W. 47th Place • ***Elizabeth, New Jersey:*** A. B. Murray Co., Inc., Post Office Box 476 • ***Philadelphia 3, Penn.:*** Rutan & Co., 1717 Sansom St. • ***San Francisco 10, Calif.:*** Pacific Metals Co., Ltd., 3100 19th St. • ***Seattle 4, Wash.:*** Eagle Metals Co., 4755 First Ave. South ***Toronto, Ontario, Canada:*** Alloy Metal Sales, Ltd., 181 Fleet St., E. • **Bundyweld nickel and Monel tubing is sold by distributors of nickel and nickel alloys in principal cities.**



This picture* does not equal 10,000 words

This is a fine photograph—but men and machines are only part of the story at IGW. It takes esprit de corps (a much overworked term that fits here)—it takes pride of workmanship to produce fine precision gears and parts.

* This Horizontal Jig Borer is typical of the high precision tools designed and built by Indiana Gear for their own use.

Indiana GEARS

GEARS • CAMS • INTRICATE AND PRECISE MACHINE PARTS

INDIANA GEAR WORKS • INDIANAPOLIS 7, IND.

associated with the paint industry since 1907 and with Pittsburgh Plate since 1939.

♦

Charles F. Keyser has been appointed central district sales manager of Shakeproof Inc., a division of Illinois Tool Works, Chicago. This district is comprised of the states of Illinois, Iowa, Minnesota, Missouri, Wisconsin, Michigan, Indiana and Ohio.

♦

Herbert J. Heesch was recently made field sales supervisor of Hooker Electrochemical Co., Niagara Falls, N. Y. He will be responsible for co-ordinating the activities of field salesmen and district sales managers.

♦

Appointment of sales managers for the Chicago, Cincinnati and Rochester, N. Y., district offices of Tinnerman Products Inc., Cleveland, has been announced. **Chris Ringhaver,** district sales manager of the company's western New York district in Rochester, has been appointed district sales manager of the Chicago office. He is succeeded by **Thomas M. Landfear,** who has been associated with the Cleveland office since 1950 and has served in the general sales department and the Cleveland district office. **Herman H. Welland** has been appointed sales manager of the Cincinnati office, where he has been located for three years.

♦

Kenneth G. Hubach has been appointed sales manager of the foundry and commercial weldment departments of Baldwin-Lima-Hamilton Corp., Philadelphia. He will be concerned with the development of long-range possibilities in the field of metal fabrication.

♦

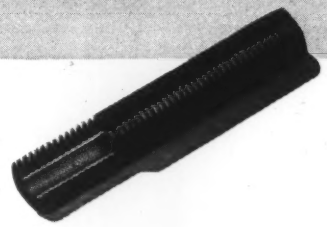
The appointment of **Fred J. Ebeling** to the newly created post of general sales manager of the Dodge Mfg. Corp., Mishawaka, Ind., was announced recently.

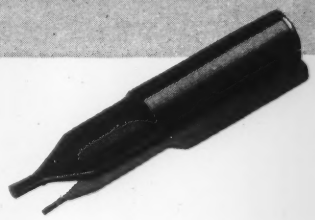
♦

E. Stephen Farlow has been appointed manager of a sales office recently opened in Baltimore by Sterling Electric Motors Inc., Los Angeles.

2 WOLVERINE DEVELOPMENTS THAT SHOULD COMMAND YOUR IMMEDIATE INTEREST

These developments are only two of the many that Wolverine offers. They represent new opportunities for designing tubular parts which will require the use of less material, and will improve production efficiencies. They are important contributions to the defense program and help to utilize the available copper to the best advantage.





WOLVERINE TRUFIN*

Because of its unique construction, Wolverine Trufin* will withstand vibration and sudden temperature changes without impairing heat transfer qualities. The ratio of outside surface area to inside surface area is often as high as 19 to 1. Such high ratios permit smaller, more compact and usually more efficient operating units, which in turn makes for fewer components and less material, as well as substantial saving of labor in assembly.

*Reg .U. S. Pat. Off.

SPUN END PROCESS*†

is a fast, economical and efficient method of forming the end of tubular parts. It has, in many cases, supplanted other methods of fabrication. The spun end process can produce a wide variety of end forms ranging from long shapes to sharply turned ends—with or without apertures.

This process brings you lower costs in construction and assembly which is of such vital interest to all industry.

† A Patented process RE 22465

Send for more detailed information about these Wolverine tube developments.

Wolverine Trufin and the Wolverine Spun End Process available in Canada through the Unifin Tube Co., London, Ont.

WOLVERINE TUBE DIVISION

Calumet & Hecla Consolidated Copper Company

INCORPORATED

Manufacturers of seamless, nonferrous tubing

1433 CENTRAL AVENUE • DETROIT 9, MICHIGAN

PLANTS IN DETROIT, MICHIGAN AND DECATUR, ALABAMA

Sales Offices in Principal Cities

Export Department, 13 E. 40th St., New York 16, N. Y.

- Custom Engineered and Tested
- Using all known Spring Metals
- Hot or Cold Wound

Be sure you select the right spring for the job by having your spring requirements thoroughly engineered.

Let us help you with your spring specifications. Our experience over many years in the manufacture of all types of springs for every conceivable application is available to you without obligation.

Fill out the coupon below for "custom engineering" of your spring requirements.

AMERICAN-FORT PITT SPRING DIVISION
H. K. PORTER COMPANY, INC.
2 John Street, McKees Rocks, Pa. *(Pittsburgh District)*

American-Fort Pitt Spring Division
H. K. Porter Company, Inc.,
2 John Street, McKees Rocks, Pa.
Gentlemen:
Have a sales engineer call on me to discuss custom engineering our spring requirements.

Name of Company_____ Date_____
Address_____ City_____ State_____
Name_____ Title_____

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SALES Notes

A NEW corporation, **CEC Instruments Inc.,** has been formed as a subsidiary organization to handle sales and service work on instruments manufactured by **Consolidated Engineering Corp.** Main office of the new corporation will be at the Consolidated plant, 300 North Sierra Madre Villa, Pasadena 8, Calif. Branch offices are already in operation in New York City, Philadelphia, Dayton, Chicago, and Washington, D. C.

♦

As a further step in the consolidation of related product lines, The Lima Div. and the Austin-Western Co., a wholly owned subsidiary, have been combined into one internal operating unit of **Baldwin - Lima - Hamilton Corp.,** Philadelphia. Products of both organizations will continue to be sold under present names and trademarks.

♦

Conoflow Corp., Philadelphia, has appointed **Instrument Sales Corp.,** 2137 Second Ave., Seattle, Wash., as representative in the Pacific northwest area, including Washington, Oregon, and northwest Idaho. Conoflow has also appointed **Bruce Greaves Co.** of St. Louis to serve the eastern part of Missouri and southwestern Illinois.

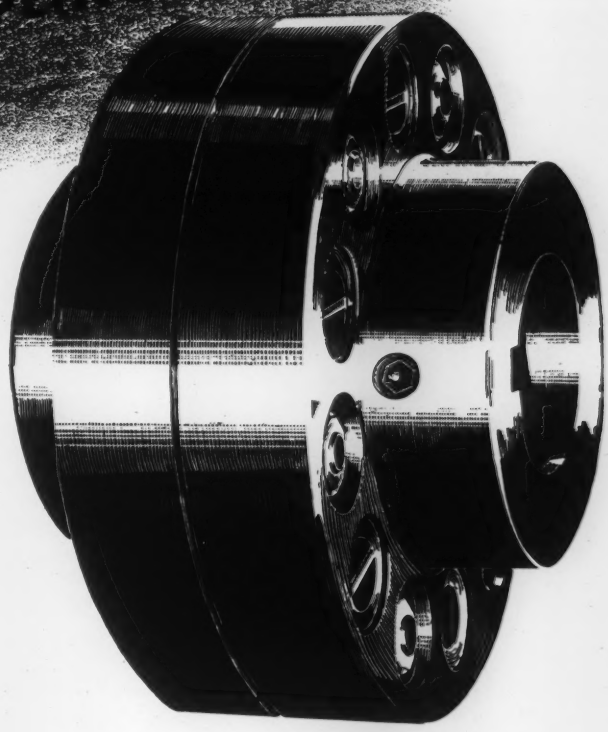
♦

Announcement has been made of the appointment of **Wear Associates,** 4016 Colgate Ave., Dallas 5, Tex., as representative in the northern Texas area for **Colonial Broach Co.,** Detroit, and **Colonial Bushings Inc.,** Fraser, Mich.

♦

Allis-Chalmers Mfg. Co., Milwaukee, recently announced the following appointments: **Oattis Electric Supply Co. Inc.,** 240 North Front St., Memphis, Tenn., as distributor for motors, controls, pumps, transformers and Texrope drive equipment in portions of Tennessee, Mississippi, Kentucky, Missouri and Arkansas, and **Flushing Electric**

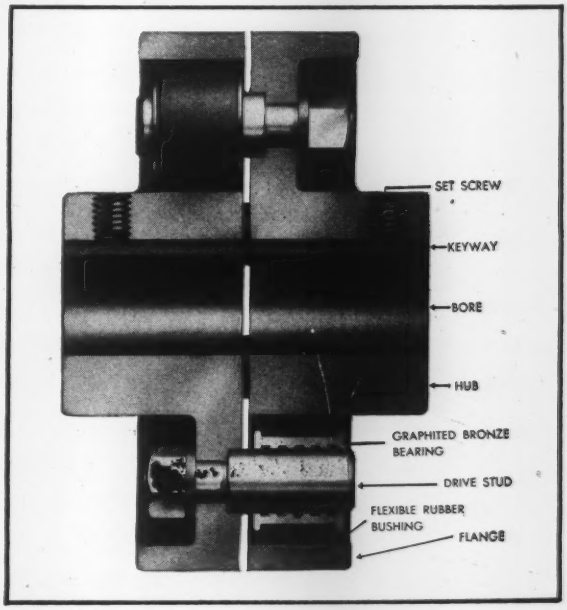
WHEN DESIGN ENGINEERS THINK OF RUBBER BUSHED FLEXIBLE COUPLINGS



THEY THINK OF

AJAX

as America's standard



● 30 Years of satisfactory performance on direct-connected generators, pumps, compressors, winches, speed reducers and other similar equipment have proved the economy of protecting good machinery with Ajax Flexible Couplings.

They protect bearings, gears, armatures, impellers and other costly working parts against unavoidable angular and offset misalignment.

Ajax Flexible Rubber Bushings provide a quiet, cushioned drive in both directions of rotation.

Ajax oilless bronze bearings are self-lubricated for life.

No problems are set up by centrifugal force. They operate successfully in abrasive-laden air. They operate vertically or horizontally.

Free end float lets electrical machinery find its magnetic center without interference.

Standard Ajax Couplings are made of forged steel or cast semi-steel. Aluminum, bronze and other metals available for special applications. Made in a wide range of sizes and capacities...write for catalog.

AJAX FLEXIBLE COUPLING CO. INC.

WESTFIELD, NEW YORK

PLATECOILS
REPLACE PIPE COILS

cut costs again

The C. A. Dauer Co., Detroit, Michigan, has found they get more efficient heat transfer at lower cost when they equip their bonderite systems with Platecoils. Use of Platecoils has these five advantages:

Lower first cost.
Simplified and less costly installation.
Takes less space in tank.
Higher heat transfer rate.
No pipe joints in solution.

The 5-Stage Dauer Bonderite Washer pictured above has Platecoils in all five stages. It has electro-polished stainless steel Platecoils in the Bonderite stage and cold rolled steel Platecoils in the other four stages. Because the Platecoils have so much greater prime surface in a given area, smaller size Platecoils can be used. As a result, the initial cost is less, tank capacity is increased and installation is simplified. The Platecoils are easily installed, using simple supports instead of the complicated racks needed for pipe coils. As there are no threaded joints in the solution, the Platecoils are much easier for Dauer's customers to remove for cleaning or repairs. They can be removed and replaced without dumping the solution. Why continue to use costly pipe coils when Platecoils heat or cool so much more efficiently at but a fraction of the cost! Send for bulletin P71 today.

PLATECOILS *for* TANK HEATING *and* COOLING

Corp., 45-07 162nd St., Flushing, N. Y., as a distributor for motors and control in Queens, Suffolk, Nassau, Kings, Bronx, New York, and Westchester counties in the state of New York.

♦

Hewitt-Robins Inc., Stamford, Conn., has opened an office in the Porter Bldg., 406 West 34th St., Kansas City, Mo.

♦

American-Fort Pitt Spring Div. of **H. K. Porter Co. Inc.,** Pittsburgh, recently appointed two new exclusive sales representatives. **John J. Gillis Co.,** 447 Statler Bldg., 20 Providence St., Boston 16, Mass., will cover the New England area, and **Sales Engineering Co. Inc.,** 875 Legrand St., Salt Lake City 5, Utah, will service accounts in Utah, Nevada, Wyoming, Montana, and Idaho.

♦

The Electric Products Co., Cleveland, has appointed **Robert A. Young & Co.,** Glendale, Calif., as sales and service representative for southern California and the state of Arizona.

♦

Four new representatives have been appointed by **Farr Co.,** Los Angeles, air filter manufacturer. **Donald Southard** of Denver will represent Farr in the Colorado and Wyoming territory; **F. W. Jenike Co.,** Cincinnati, in the Cincinnati area and the state of Kentucky; **The Charlie Wood Co.,** Columbus, in Columbus, Dayton, Mansfield and Coshocton; and **The William M. Shank Co.,** Indianapolis, in southern Indiana.

♦

John Bouchard & Sons Co., Nashville, Tenn., has been appointed a distributor for Republic Rubber Div., **Lee Rubber & Tire Corp.,** Youngstown.

♦

Sundstrand Machine Tool Co., Rockford, Ill., has announced the formation of a wholly owned subsidiary, **Sundstrand International Corp.,** to conduct the export business of the various divisions of the parent company. Richard H. Olson, former director of Sundstrand export sales, was elected vice president of the new subsidiary and will head its operation.

IMPROVED

HAGEN

SYNCHRONOUS MOTOR

MOST POWERFUL SYNCHRONOUS MOTOR FOR ITS SIZE

Manufactured to
Highest quality standards

48 in. oz. starting torque at 1 RPM.
40 in. oz. synchronous torque at 1 RPM.
Voltages up to 550
(without resistors or accessories.)
Frequencies 25 to 60 cycles.
Interchangable coils for different voltages.
Exposed coil for greater heat radiation.
Rigid metal gear case.
Available in reversible type motor.

HAGEN MANUFACTURING COMPANY INC.
MOLINE, ILLINOIS

Subsidiary of
EAGLE SIGNAL
CORPORATION

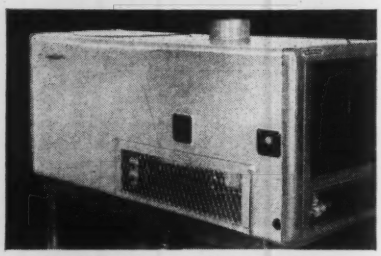
Sicon*

HEAT-RESISTANT FINISH

**A PRODUCT OF THE SILICONES*

1. Sicon Protects Gas Heater Combustion Chambers at 875°

2. Sicon in COLORS Preserves Appearance of Heating Equipment Indefinitely



CENTRAL GAS HEATER
Mfg'd by the JOHN ZINK CO., TULSA

For years the protection of combustion chambers and outer coverings of heating equipment has been a problem.

The John Zink Company, a leading manufacturer of gas heaters, solved this problem with SICON.

SICON protects their combustion chambers against extreme high heats of 875° without powdering or losing its color.

SICON, in attractive colors, also preserves the outside appearance of their products, adding greatly to sales appeal, and prolonging life.

The John Zink Company now uses SICON for all hot applications.

Inside and outside—SICON is the finish that can often do the job where all others fail.

WRITE FOR LATEST TECHNICAL DATA TODAY

Sicon

Silicone-Base Finish is manufactured exclusively by

MIDLAND INDUSTRIAL FINISHES CO.
Waukegan, Illinois
ENAMELS · SYNTHETICS
LACQUERS · VARNISHES

Meetings

AND EXPOSITIONS

Sept. 4-5—

National Conference on Industrial Hydraulics. Eighth annual meeting to be held at the Sherman Hotel, Chicago, Ill. J. G. Duba, Illinois Institute of Technology, Technology Center, Chicago 16, Ill., is secretary.

Sept. 8-10—

American Standards Association. Third National Standardization Conference will be held in conjunction with the Centennial of Engineering at the Museum of Science and Industry, Chicago, Ill. Additional information may be obtained from society headquarters, 70 East 45th St., New York 17, N. Y.

Sept. 8-11—

American Society of Mechanical Engineers. Fall meeting to be held at the Sheraton Hotel, Chicago, Ill. C. E. Davies, 29 West 39th St., New York, N. Y., is secretary.

Sept. 8-12—

American Society of Mechanical Engineers. Industrial Instruments and Regulators Division, joint conference with Instrument Society of America to be held at the Cleveland Auditorium, Cleveland, Ohio. C. E. Davies, 29 West 39th St., New York 18, N. Y., is secretary.

Sept. 11-14—

Packaging Machinery Manufacturers Institute. 20th annual meeting to be held at the Homestead, Hot Springs, Va. Additional information may be obtained from society headquarters, 342 Madison Ave., New York 17, N. Y.

Sept. 22-23—

Steel Founders' Society. Fall meeting to be held at the Homestead, Hot Springs, Va. Additional information may be obtained from society headquarters, 920 Midland Bldg., Cleveland, Ohio.

Sept. 22-24—

American Society of Mechanical

The new

BELLOW SEAL BOOT

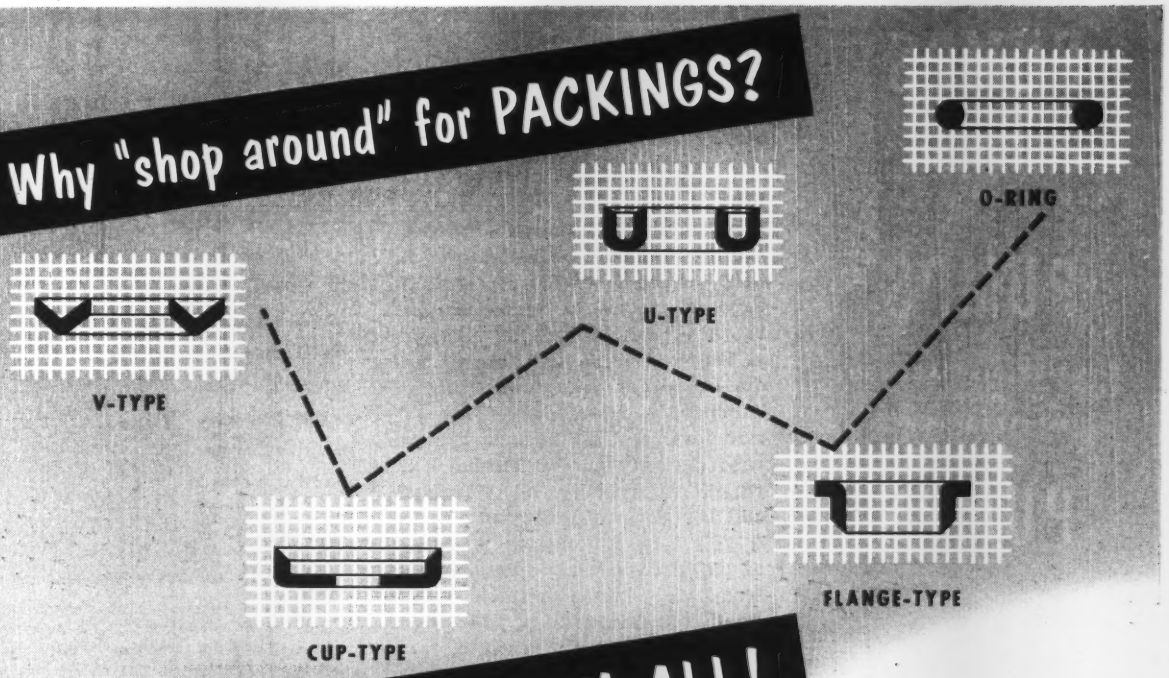
can now be ordered directly from stock

Previously available only on special order, you can now get off-the-shelf delivery in stock sizes. The new BELLOW SEAL completely seals out dust and grit from sliding shafts. Inexpensive and easy to use, they are made from Neoprene coated fabric and are oil resistant. These seals are also available in Fyresafe Cloth which is flame resistant and are a suitable application on such equipment as buttwelders, etc. where it is necessary to provide against sparking. Write today for descriptive literature.

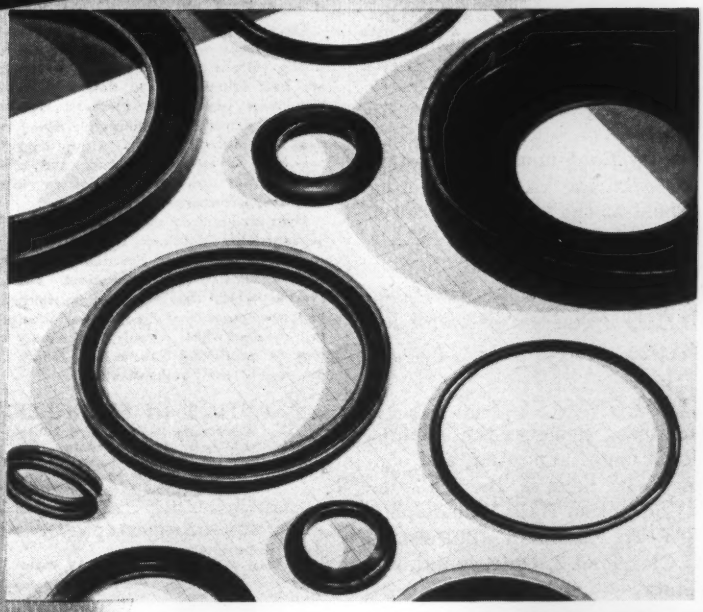
A bearing is no better than its seal

THE GARDAN MFG. CO.
P.O. BOX 34, NEW CASTLE, PA.

Why "shop around" for PACKINGS?



HOUGHTON HAS THEM ALL!



One reliable source for all your hydraulic and pneumatic packing needs . . .

One complete line for V, Cup, U, Flange and O-ring designs—in leather of various impregnations and in synthetic rubber, both fabricated and homogeneous types . . .

One responsibility for design-engineered packings that *fit* . . .

That's the kind of service the Houghton Man is giving and the kind he offers you, too.

Doesn't it make sense to talk over your packing problems with the Houghton Man first?

And if you want full details on Houghton *Vim* Leather and *Vix-Syn* synthetic rubber packings, gaskets and adaptors right away, write to E. F. Houghton & Co., Philadelphia 33, Pa.

GET THIS "PACKING STANDARDS" BOOK NOW—it's accepted as the standard by industry and will be mailed without cost on request.

VIM and VIX-SYN PACKINGS
. . . Products of

E. F. HOUGHTON & CO.
PHILADELPHIA • CHICAGO • DETROIT • SAN FRANCISCO

Ready to give you on-the-job service . . .

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FOR COOLANTS, LUBRICANTS, AND ABRASIVE LIQUIDS

PUMPS

POSITIVE DISPLACEMENT AND IMPELLER TYPES

PUMPS

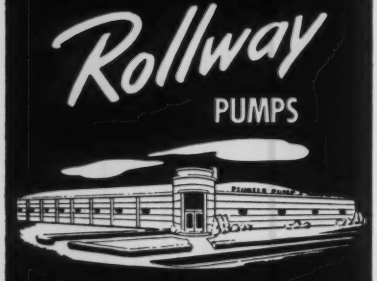
J. I. C. STANDARDS OR DIRECT MOTOR CONNECTED

PUMPS

DEPENDABLE, ECONOMICAL, EFFICIENT

STANDARD OR SPECIAL, FOR EVERY MACHINE TOOL AND INDUSTRIAL USE

Rollway PUMPS



Pioneer PUMP

& MANUFACTURING CO., INC.

19652 JOHN R STREET
DETROIT 3, MICHIGAN

WRITE FOR CATALOG

Engineers. Petroleum mechanical engineering conference to be held at Hotel President, Kansas City, Mo. C. E. Davies, 29 West 39th St., New York 18, N. Y., is secretary.

Sept. 29-Oct. 1—

National Electronics Conference. Eighth annual conference to be held at the Sherman Hotel, Chicago, Ill. under the sponsorship of the American Institute of Electrical Engineers, the Institute of Radio Engineers, Illinois Institute of Technology, Northwestern University, and the University of Illinois, with participation by Purdue University, University of Wisconsin and the Society of Motion Picture & Television Engineers. Additional information may be obtained from S. R. Collis, Chairman, N.E.C. Publicity Committee, 208 West Washington St., Chicago, Ill.

Oct. 16-17—

Gray Iron Founders' Society. Annual meeting to be held at Hotel Cleveland, Cleveland, Ohio. Additional information may be obtained from society headquarters, National City Bank Bldg., Cleveland 14, Ohio.

Oct. 16-18—

Foundry Equipment Manufacturers Association. Annual meeting to be held at the Greenbrier Hotel, White Sulphur Springs, W. Va. Additional information may be obtained from society headquarters, 1213 West 3rd St., Cleveland 13, Ohio.

Oct. 20-24—

American Society for Metals. National metal exposition and congress to be held at the Philadelphia Convention Hall, Philadelphia, Pa. W. H. Eisenman, 7301 Euclid Ave., Cleveland 3, Ohio, is national secretary.

Oct. 22-24—

Porcelain Enamel Institute. 21st annual meeting to be held at the Greenbrier Hotel, White Sulphur Springs, W. Va. Additional information may be obtained from society headquarters, 1010 Vermont Ave., Washington 5, D. C.

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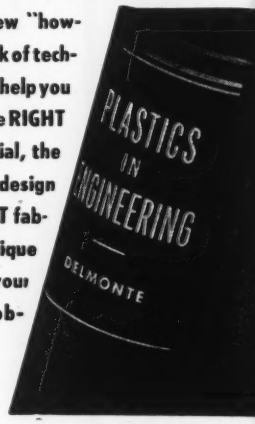

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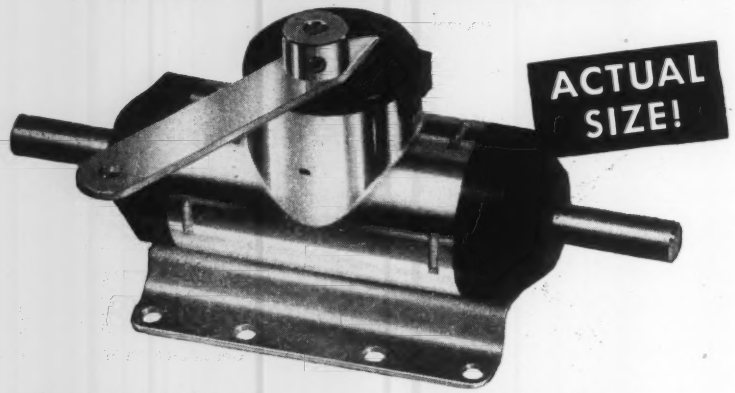

- Compact! Only 4 3/16" overall
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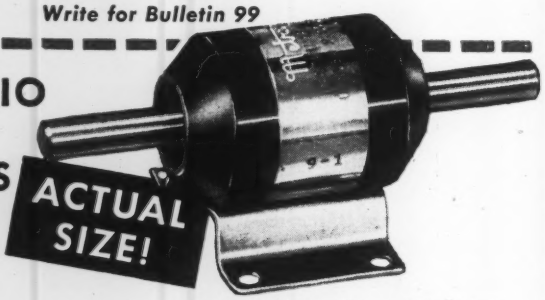
Write for Bulletin 99

FIXED RATIO SPEED CHANGERS (Gear Type)



- Only 1.050" diameter!
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- Hobbed gears for smooth, precision running
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Heating and Ventilating

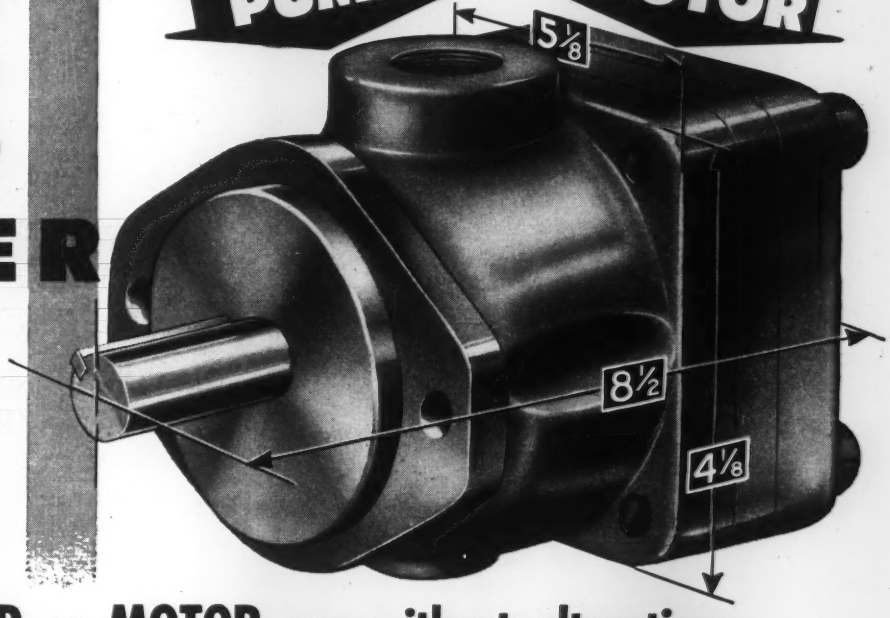
Dehumidifier: Precision portable Model 25CT for laboratory and industrial use. Features separate reactivation air-intake vent, which makes it particularly adaptable for maintaining constant low humidity levels at constant controlled temperatures. Operating temperatures range from −40 to 100 F. Draws humid air through permanent dehydrating agent—a combination of activated alumina and silica gel—and discharges dry, dustfree air back into room. Dries for 2½ hours and vaporizes absorbed moisture for 30 minutes, switching from drying to reactivation automatically. "Time-delay action" feature assures that desiccant is thoroughly dehydrated and cooled before unit switches back to drying phase, thereby preventing undue rise of temperature at outset of the drying cycle, and increasing drying efficiency about 2 per cent. Has self-contained 1/100-hp, 24-watt fan motor capable of moving 32 cu ft of air per minute through machine. Size: 21 in. high, 14 in. in diameter. *Dryomatic Corp., Alexandria, Va.*

Materials Handling

Tilting Top Truck: Designed for positioning broach holders. Table top rotates 360 deg on a horizontal axis and can be locked in place wherever stopped. Back plate supports broach holders and fixtures as table tilts work to convenient position for service. Table is 30

Your best buy in compact POWER

a hydraulic PUMP or a hydraulic MOTOR



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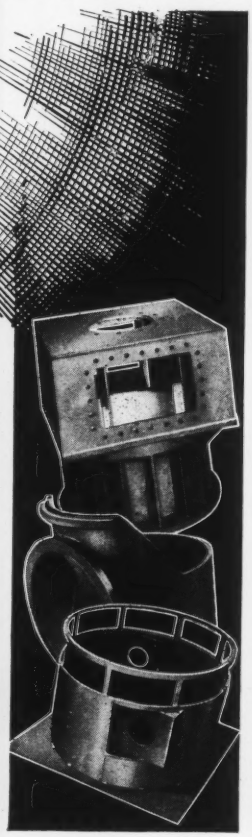

Littleford Weldments have four basic advantages:

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4. ADAPTABILITY—Weldments adapt themselves to changes and improvements at any time with minimum of cost.

Littleford complete fabricating service and 70 years experience in laying out, forming, shearing and welding all types of metals is assurance of quality weldments regardless of size. Write for Weldment Bulletin.

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in. from floor. Rides on two wheels and four casters. Capacity, 3000 lb. May be built to alternate specifications. *The Hamilton Tool Co., Hamilton, O.*

Fork Lift Trucks: Gasoline powered Model FT30-15 and diesel powered Model FTD30-15, rated at 3000-lb capacity at 15-in. load center. Mechanical features include removable wet sleeve cylinder liners for low maintenance cost, quick change 11-in. industrial clutch, single - lever gearshift mounted on steering column for operator convenience, center point steering. Available in five standard masts with 72, 84, 108, 114 and 120-in. lifts. *The Buda Co., Harvey, Ill.*

Paper Roll Clamp: Hydraulically actuated assembly for use on Mercury fork trucks. Quickly detachable self-sealing pressure connections; plug and socket type electrical connections. Has "flipper" arrangement which facilitates picking up horizontally disposed rolls without blocking or employing the usual special forward tilt range. Rolls can be removed from tightly packed shipments by sliding them sideways. Hydraulic system maintains continuous and positive clamping action. Clamps available to handle rolls up to 5000 lb. *Mercury Manufacturing Co., Chicago, Ill.*

Hand Dump Truck: For catching and holding scrap, etc. Capacity, about ½ cu yd. Size: top, 25¾ by 45 in.; bottom, 25¾ by 27 in.; height of side panel is 17½ in.; overall height, 23 in. Can be furnished higher or lower. Has two 8-in. steel wheels and two 4-in. metal swivel wheels. Weighs approximately 125 lb. *Palmer-Shile Co., Detroit, Mich.*

Metalworking

Precision Profiler: Redesigned unit is heavier than predecessor. Has powerful V-belt drive and new cutter collets. Same size collet is used in follower spindle. For profiling, milling, slotting, recessing and routing operations on a variety of small mechanical parts. Standard 1750 rpm, 1/3-hp, three-phase motor provides eight spindle speeds ranging from 437 to 7000 rpm; 3450 rpm, 1/3-hp, three-

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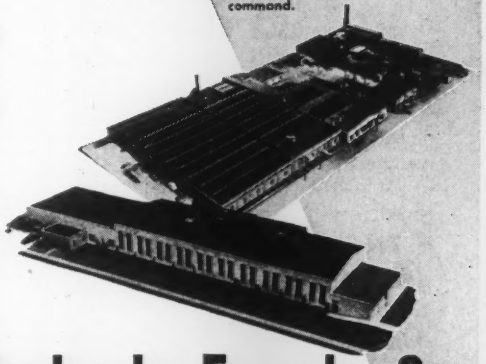

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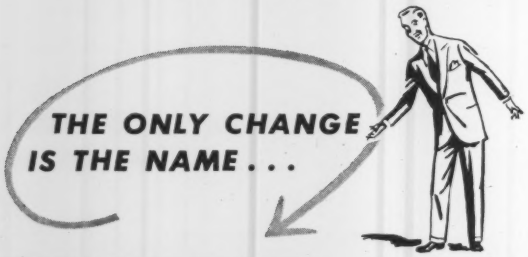

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phase motor provides eight spindle speeds ranging from 875 to 14,000 rpm. Working area is 2 by 4 in. horizontal, 1¼ in. vertical. Floor space required, 24 by 26 in.; height, 57 in. *The Wade Tool Co., Waltham, Mass.*

Angle-Head Drill: Small pneumatic unit permits drilling in close quarters. Angle head can be swiveled to any position relative to the housing by loosening a single nut. Air motor has built-in regulator which allows for variable speed ranges; also has built-in automatic oiler. Furnished with ½-in. capacity Jacobs geared chuck, key, lubricant, hydraulic fitting and rubber air hose assembly. *Mall Tool Co., Chicago, Ill.*

Power Press: Electromatic Model 59 has 18-ton capacity. Features instant-action, electrically-operated nine-point jaw clutch. Activated by foot control or optional hand controls. Limit switch on clutch housing provides absolute single stroke control. Selector switch readies press for either single stroke non-repeat, or continuous action, without stopping press. Neutral position makes clutch inoperative. Electronic timer converts press into a fully automatic machine. Bijur hand oiling system is available. *Famco Machine Co., Kenosha, Wis.*

Precision Boring Machine: Style 425 automatic vertical unit for multiple precision boring, turning and facing operations; can be used for semifinishing work as well. Has two fully counterweighted vertical slides operated by hydraulic cylinders. Each slide carries a cross slide also hydraulically powered. A 36-in. diameter table is supported on a vertical spindle mounted in 24-in. tapered roller bearings and driven through a precision worm at speeds up to 500 rpm. All slide movements, work speed control, lubrication and coolant control are automatic. *Ex-Cell-O Corp., Detroit, Mich.*

Tube Bender: Capacity, ¾-in. Features versatile operating circuit which permits individual control of all functions at any time during cycle. Mandrel, clamp die, and pressure die operate automatically or independently. Tooling results can be checked easily at any given point. Has pick-off angle-of-bend

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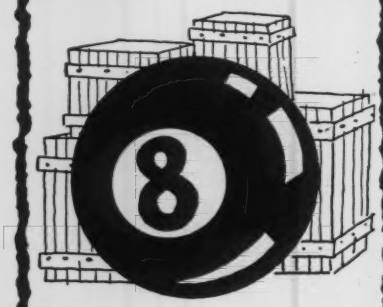

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turret and a removable location-of-bend stop assembly, for repeat set-ups. Occupies 33 by 130 in. floor area; accommodates 7-ft tube over the mandrel. For longer tube lengths, base extensions can be provided. Bending arm speed, 25 rpm. Handles stainless steel tubing 1 in.-16 gage, I.P.S. extra heavy pipe up to ¾ in., and non-ferrous metals 1¼ in.-0.134 wall thickness, as well as extruded shapes within its capacity range. Maximum standard radius adjustment, 10 in. *Pines Engineering Co. Inc., Aurora, Ill.*

Pneumatic Riveter: Can be used for riveting, de-riveting, punching, forming and stamping by changing tools. Designed for bench installation. Foot control furnished; hand or automatic control may be used. Air pressure of 100 psi produces working pressure of 1100 lb with 11/16-in. stroke. Overall height, 16 in., weight, 37 lb; throat clearance, 3½ in. *Barrett Equipment Co., St. Louis, Mo.*

Copying Attachment: Hydraulically operated Swiss Bondycop makes it possible to turn almost any lathe into an automatic tracer controlled machine. Machining is done in a fraction of normal time; setting requires only a few minutes. Can be fitted to almost any lathe; need not be removed when not in use. Uses for a pattern either the first piece of a batch or a jig. Will copy angle up to 90 deg in traverse toward the headstock. Standard size unit can be used for all diameters up to 6 in.; can be supplied in sizes 40 to 80 in. between center points. *Morey Machinery Co. Inc., New York, N. Y.*

Jig Borer: Small-size Model No. 1E for precision locating, drilling and high-speed boring in small work. Features heavy, wide bed; table and carriage way telescoping guards; built-in Electrolimit measuring system; new design quill mounting and handy control center for fast, easy operation. Table settings accurate within 0.0002-in. can be made quickly with Electrolimit measuring system. Two measuring units, independent of traversing screws, control longitudinal and transverse settings. Basic 1-in. spacings are obtained electromagnetically from solid master bar

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For example, since Thomas Edison invented the incandescent filament lamp in 1880, the electric light industry has grown to an annual volume of $501,500,000 in light bulbs alone; in May, 1906 the Wright Brothers received the patent for their flying machine; the value of aviation manufactures in 1951 in the United States alone was estimated at $3,350,000,000 and in February, 1952, records show a $10½ billion backlog of orders.

More rapid still is the growth of the radio-television industry which today produces some $230 million worth of home radio sets and $1,570,800,000 in television sets. In every case, employment and sales volume grew enormously and the public enjoyed huge personal benefits.

Side by side with Invention came Research, exemplified by the competition of intelligent men questing for new materials, new methods, new processes, new scientific truths. Current advertisements tell of hundred-year tests to assure better materials for the future, technology that produces metals to withstand almost inconceivable heat, machines calculating 20,000 times faster than the mind of man, medicines that cure "incurable" diseases, food processes that cook, sterilize and pack hundreds of cans a minute. And in every case, the public enjoys huge personal benefits.

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Without free competition, American progress stops. No country can long exist when its government calls all the shots. We need competition to assure progress for people.

★ ★ ★

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My occupation (type of engineer)

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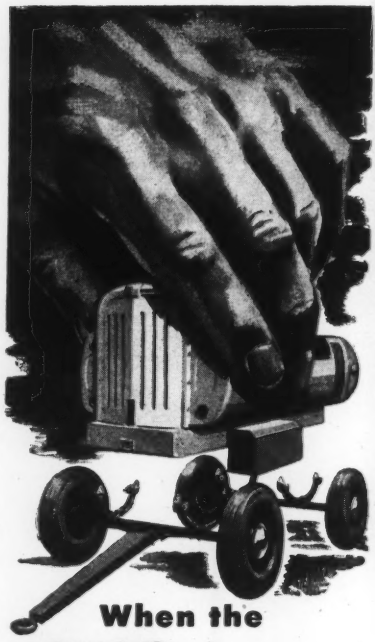
and registered visibly by a zero reading on an indicating meter. Fractional inches are obtained by moving small electromagnetic unit between inch spacings on master bar with a superprecision micrometer screw. Has 16 spindle speeds ranging from 65 to 2800 rpm and 4 spindle feeds, both up and down, ranging from 0.0006 to 0.006 inches per revolution. Two table sizes available—12 by 24 in. with 18-in. longitudinal travel and 12-in. transverse travel, and 12 by 42 in. with 36-in. longitudinal travel. Has 20-in. capacity between table and spindle. *Pratt & Whitney, Div. Niles-Bement-Pond Co., West Hartford, Conn.*

Flame Cutter: Portable, hand-operated machine will flame cut plate ranging in thickness from 5/64 to 2¼ in. For straight and I-beam cutting; can also be used for circle cutting to a minimum radius of 1 in. Torch can be set at any angle for bevel cutting. Weighs 19 lb. *American Pullmax Co. Inc., Chicago, Ill.*

Hole Punching Units: Type "H" units for punching flanges, angles, container sides and similar shaped and formed work. Punches move horizontally rather than vertically. Independent and self-contained; all parts—punch, die guide and stripping spring—are held as a unit by holder. Holder assures accurate alignment of punch and die. Patterns are set up outside the press, reducing downtime. *Wales-Strippit Corp., North Tonawanda, N. Y.*

Face Grinder: In one operation, grinds two flat opposing surfaces within close limits of accuracy. Grinding disks are mounted on horizontal spindles; faces are inclined slightly towards each other. Each wheelhead is independent and is adjustable with respect to the opposite head in increments of 0.0001-in. to maximum distance of 11½ in. Truing attachment mounts two diamonds and incorporates a compound slide capable of accurate movement both parallel to and at right angles to spindles. Also, top slide can be slightly swiveled, so that an angular face or lead can be given to disks when required. Large workpieces are fed between grinding disks by means of an endless-chain conveyor. Suitable flat workpieces may be fed through



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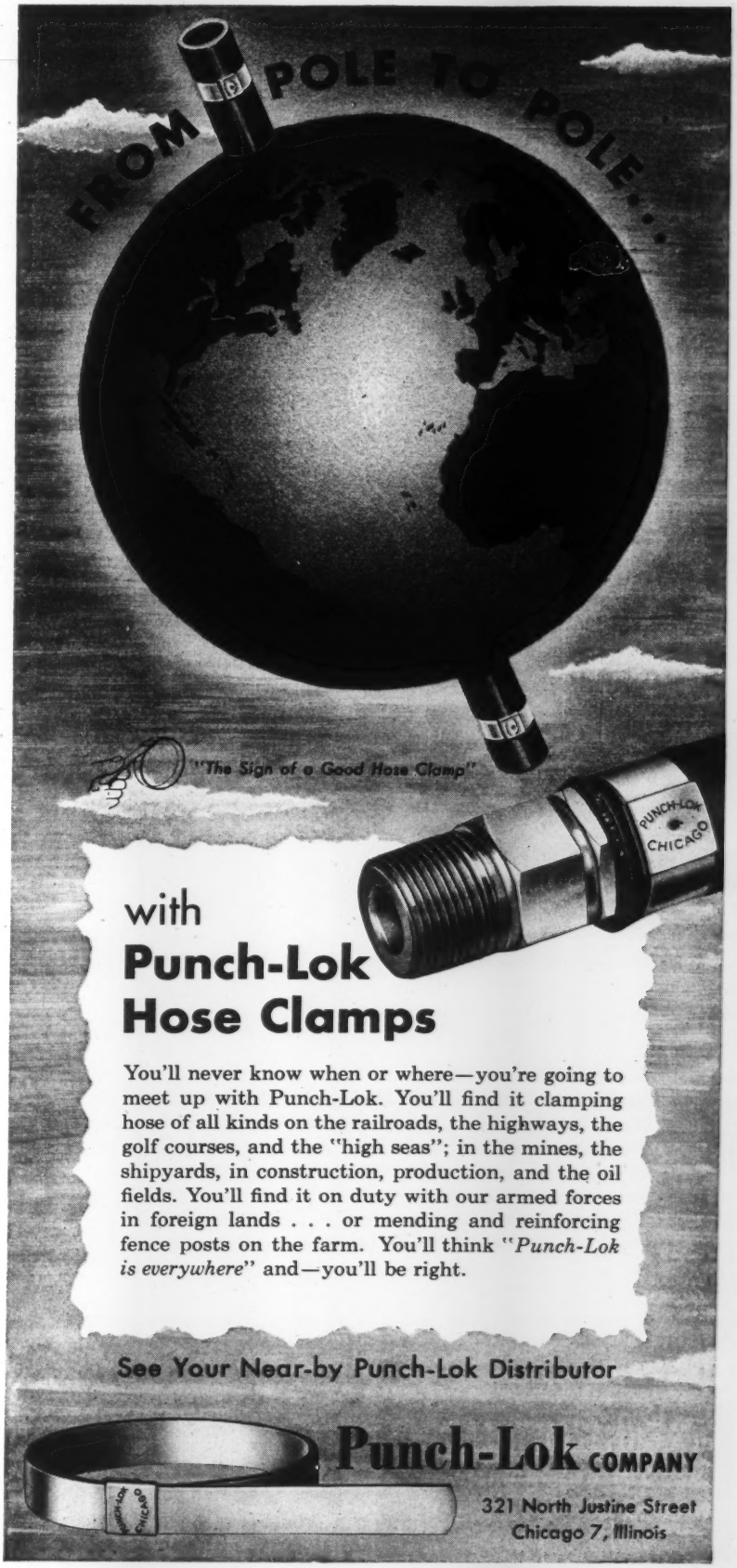
between two vertical pressure rollers which force the pieces through grinding passage along a horizontal workplate. Other flat pieces are handled by a flat circular work carrier containing holes or pockets to accommodate pieces inserted by hand. Grinding disks have 24-in. diameter, 16-in. hole; are 3 in. wide. Workhead motor has 16 speeds. *Arthur Scrivener Ltd., Birmingham, England.*

Tapping Attachment: Eliminates possibility of double threading pretapped holes. Finishing tap is allowed to rotate at full speed, and on being fed into pretapped hole, automatically picks up thread correctly. Taps holes at a cutting speed of 300 fpm; taps blind holes in light metal at spindle speeds up to 2500 rpm. Torque, adjustable according to graduated scale, is transmitted through a mechanical locking device utilizing steel balls and springs. Reversing device with mechanical clutch permits rapid reverse action through a specially designed radial bearing. Models available with the following capacities: Tap No. 0 to No. 5, No. 4 to ¼-in., No. 10 to ½-in., ½-in. to 1⅛ in., 1 to 2 in. *Eric S. Johnson Co., Chicago, Ill.*

Electric Screwdriver: Brace of hand tools for use at right angles to work. Model SD-1 drives free-running screws or nuts from No. 0 to 4; has driver-bit speed of 1200-1400 rpm, weighs 12 oz, is 4¾ in. long; Model SD-2 drives sizes No. 4 to 8, has driver-bit speed of 1400-1600 rpm, weighs 18 oz, is 6½ in. long. Can also be used for unscrewing by inserting a bit into top chuck and turning the machine over. Operates on 110-115 v, ac or dc; also available for 220 v operation. *Dremel Mfg. Co., Racine, Wis.*

Radial Drilling Machine: Heavy-duty unit in sizes from 3 to 8 ft. Arm moves on sleeve on three guiding surfaces. When unclamped, saddle can be moved by hand on rollers on a strip of hardened spring steel. Disk clutch permits smooth starting of drilling spindle. *Diamond Machine Tool Co., Los Angeles, Calif.*

Forging Presses: High-speed machines in capacities from 300 to 4000 tons. Feature heavy-duty air-operated friction clutch and air-re-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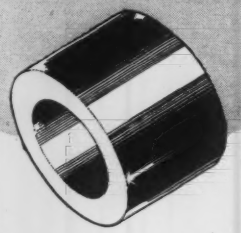

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lease, spring-set brake, both mounted on heavy full-eccentric main shaft. Load indicator registers actual load on press by measuring elongation of frame uprights. Self-contained die seat has easily operated wedge adjusting mechanism. Die seat can be bumped to correct front-to-back alignment without disturbing adjusting mechanism. Wedges can be inserted above die seat between sides of lower die and frame uprights for precision side-to-side alignment. Front of slide has long and continuous gib ways extending up into crown to keep dies in alignment when off-center loads are applied. *E. W. Bliss Co., Canton, O.*

Cutting Attachment: High-speed punch type; operates with any ¼-in. capacity standard or heavy-duty electric drill at speeds of from 800 to 3500 rpm. For cutting thin materials such as sheet steel, brass, copper, or fiber, up to 19 gage. *Mall Tool Co., Chicago, Ill.*

Drilling Machines: Small hole precision units now available in single-base, multiple-spindle design. Capacities range from 0.004 to 5/16-in. hole diameter, clearances up to 8 in. from center of chuck to column, and up to 14 in. from base to chuck. Adjustable stops provided to control hole depth. One model features variable spindle speeds, between 840 and 9300 rpm, selected by a graduated handwheel speed dial. *The Hamilton Tool Co., Hamilton, O.*

Bench Grinder: Ball bearing, ¼-hp Model No. 246 for handling large, oddly shaped parts and castings. Grinder housing design permits castings or parts to be maneuvered so that both sides of each grinding wheel may be utilized. Equipped with adjustable tool rests and safety wheel guards wide enough to permit use of wire wheel brushes. Grinding wheels, one coarse and one fine, are 6 by ⅝-in. Motor operates at 2850 rpm full load, 3450 rpm no load; ac only, 50-60 cycles, single phase: 110-115 v, 125 v, 150 v, 220-230 v. *Stanley Electric Tools, New Britain, Conn.*

Processing

Finisher: Model 32-B coats material up to 48 in. wide and 3 in. thick at speds of 30 to 90 in. linear travel per minute. Higher or lower speeds available. Accessory kits make it possible to use basic unit in almost any type of production coating line where flat material is finished and controlled thickness of coating is necessary. Kits include a standard feed table with adjustable edge guide; feed conveyor that can be added to feed table; delivery table conveyor for mounting on rear of machine to carry small finished pieces away from machine and drop them onto a drying conveyor; a pair of driven feed rolls that can be mounted on front of machine in place of feed table; extra-long feed table with multiple drive rolls that can be added for handling long and heavy sheets; brushing unit with dust removing fan that can be added to long feed table; and a paint circulating pump that can be added to deliver paint to coating roll. *Gasway Corp., Chicago, Ill.*

Wet-Blast Machine: For producing refined finishes on production tools. Special abrasives suspended in water are applied by air pressure. Metal removal is negligible; close tolerances are retained on accurately machined tooling. *Abrasive Wet-Blast Inc., Niles, O.*

Testing and Inspection

Gaging Machine: For multiple gaging of critical dimensions on an automotive crankshaft. Checks main bearings for size and taper, pilot hole diameters, flange diameters and runout, thrust bearing faces, keyway locations, etc. In operation, part is placed in loading cradle elevated above gaging units for protection and ease of loading. Hand lever actuates hydraulic device to lower part into gaging position. Up to 34 or more dimensions can be gaged and read simultaneously from an air-float graph. Part is revolved on rolls to gage concentricities and runouts. Hand air-gage head checks crankpins individually for diameter and taper in three places, simultaneously. *The Sheffield Corp., Dayton, O.*

Breakdown Tester: High-voltage unit especially designed to meet requirements of ASTM D-149-44 specifications for dielectric strength of electrical insulating

materials at commercial power frequencies. Adaptable to either laboratory or production testing representative samples of electrical tape, plastic coated wire, special components, etc. Consists of suitable transformers and a special gear train and synchronous motor which make possible the increasing of voltage at a constant rate. Increases voltage at a rate of 500 volts per second until breakdown occurs. Voltage may be varied manually to meet the same specification for step-by-step procedure. Power is turned off automatically at breakdown point. Available in both 25,000 and 50,000-v models at 2 or 5 KVA rating. *Industrial Instruments Inc., Jersey City, N. J.*

Electronic Thickness Tester: Model TT for determining thickness of common deposits on a variety of base metals, including nonmagnetic metals. Determines thickness of chromium, silver, tin, cadmium, zinc, brass, copper and nickel deposits on plane as well as most curved surfaces. Is relatively insensitive to surface roughness. Tests accurately within 90 to 95 per cent, depending on type and thickness of plate. Average test requires about one minute. Minimum thickness which can be determined, 0.00005 in. Strips plate from predetermined area approximately ⅛-in. in diameter and then shuts off automatically. Thickness is read from counter on instrument panel. Operates at 105-125 v, 60 cycles ac. Size: 17 by 10 by 10 in.; weight, 27 lb. *Kocour Co., Chicago, Ill.*

Vacuum Gage: Range, 1 to 1000 microns of mercury. For all vacuum processes in the micron range, including vacuum tube manufacture, vacuum distillation, automatic exhaust machines, refrigeration service, vacuum dehydration, and laboratory and production processes. Features include: continuous reading or recording; rapid response to pressure changes —time constant less than ½ sec; interchangeable gage tubes; one-control knob for initial setting. Current need not be reset each time pressure changes. Unaffected by ambient temperature changes. Holds calibration indefinitely. Operates on 115 v ac. *Hastings Instrument Co. Inc., Hampton, Va.*

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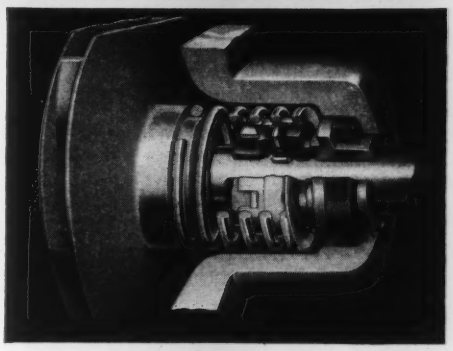

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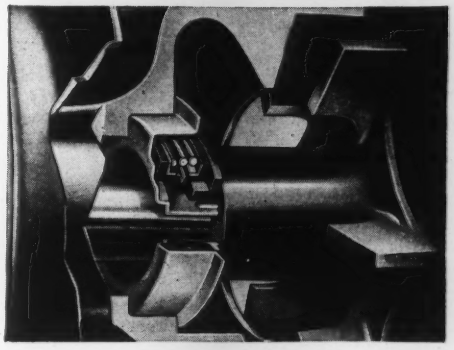

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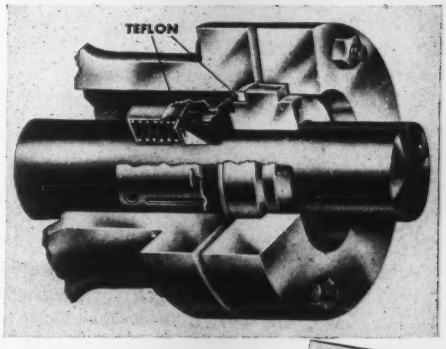

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